THE PRESERVATION OF WOOD

A Descriptive Treatise on the Processes and on the Mechanical Appliances used for the Preservation of Wood

By

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WITH 119 ILLUSTRATIONS

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PREFACE

FROM the very earliest times the supply of timber has been, in all civilized communities, a matter of the first importance. As a fuel, as a material for building construction, for shipbuilding, and as a means for internal embellishment, wood has been always in request. Recently, indeed, timber has been displaced to a considerable extent in building construction by iron, steel, and concrete, and in the structure of ships by steel; but on the other hand the amount required for interior work has largely increased, new uses for it have also arisen, and as a consequence the consumption of timber all over the world is now greater than ever.

For some years past, owing to the growing scarcity of timber and the increased demand, prices have appreciably increased, and consumers are now more frequently employing some form of preservative treatment as a means of prolonging its life so as to discount to some extent the increased cost. It is stated by experts connected with the Government of the United States that if all ties, poles, posts, piling, mine-props, shingles and structural lumber adapted to be so dealt with were given a proper preservative treatment, in that country alone there would be an annual saving of about 6,000,000,000 board feet, resulting in a financial saving of about 72,000,000 dollars, or roughly £14,400,000.

Destructive elements in the shape of the lower forms of

vegetable and animal life—bacteria and fungi or spores—are ever present and prepared to attack organic matter, and assisted by heat, air and moisture they penetrate the cells and destroy the tissue of the wood.

To render timber immune to the attacks of these agents, it is necessary to destroy them, and to impregnate the wood with some suitable antiseptic or poison. Much timber is also lost by fire, and an efficient fire-proofing or fire-retardant treatment is also desirable.

Wood preservation accomplishes three important economic purposes, viz.: Firstly, the life of durable species of wood in use is prolonged. Secondly, the life of inferior and cheaper kinds of wood is greatly prolonged. Thirdly, it enables inferior woods to be utilized which, if not subjected to preservative treatment, would be practically valueless.

The art of wood preservation is an ancient one, having been practised from a very remote period, but its use here on an extensive scale commenced when the demand was created by the railway systems, primarily for the preservation of timber for a variety of uses, and afterwards more particularly for railway ties or sleepers and crossing timbers.

The subject is dealt with in the ensuing pages in twelve chapters, the matters treated on being far too numerous to be given in detail here, but the following particulars afford some idea of the ground covered: Chapter I is introductory and, besides remarks on the liability of vegetable substances to decay, on the most suitable time for felling timber, on the definition of the term wood, and on the desirability of employing some process for the preservation of wood, includes a short account of the early history of wood preservation. Chapter II deals with the destruction of wood by decay, comprising

wet-rot, dry or sap-rot, and the effect of the latter on health; and by the ravages of insects, including molluscan wood-borers such as the teredo navalis or shipworm, the xylotrya, the lepisma, the sphæroma, the limnoria terebrans or gribble, the chelura terebrans or wood-boring shrimp, and such pests as the formica fuliginosa or black carpenter ant, the fusca or dusky ant, the formica flava or yellow ant, the termite or white ant, the red ant, the carpenter bee, beetles, etc. Chapter III is on the seasoning or drying of wood, and, after treating of natural or air seasoning, includes short descriptions of the various processes of artificial seasoning in use. Chapter IV deals with the preservative treatment of wood, the conditions essential to ensure success, the practical and theoretical aspect of the absorption of preservatives by wood, etc. Chapter V treats of the open tank or immersion method of preservative treatment and its efficiency, and gives a description of the apparatus required. Chapter VI deals with the pressure system of impregnation and with the machinery and apparatus necessary, discussing its advantages and giving the points to be considered in carrying out impregnation under pressure, and in the construction of wood-preserving works, with examples of standard plants and details of retorts, charging tram-cars, pumps, and the other mechanical appliances used in wood preservation. Chapters VII and VIII give particulars of the various preservative processes in use at the present time. Chapter IX contains a list comprising a large number of proprietary and other processes and solutions. Chapter X deals with the amount of preservatives absorbed by various kinds of woods, and with the life of preserved woods. Chapter XI is devoted to the fire-proofing or fire-retardant treatment of wood. And Chapter XII gives the cost of treating wood by the

various processes. An appendix is also added, which contains formulæ, tables and memoranda likely to be useful to those interested in the subject of wood preservation.

The book is illustrated by 119 diagrams, plans and photographic reproductions serving to elucidate the subject matter, and there is also a full index by which reference is greatly facilitated.

In conclusion, the Author desires to say that the base of the work is a paper on "The Preservation of Wood," read by him at a meeting of The Royal Society of Arts, held on the 18th February, 1914. He also takes this opportunity of rendering his thanks generally to the makers of wood-preserving machinery and others from whom he has received much valuable information and assistance, which he has endeavoured to acknowledge specifically in the text.

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Introduction

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Liability of Vegetable Substances to Decay.

VEGETABLE substances, in conjunction with animal substances, when divested of life, are liable to decay. All woods are not equally affected, some kinds being more liable, under the same conditions, to deteriorate rapidly than others, but all of them when subject to certain conditions become deprived of their fibrous textures, and thus lose their properties. This tendency to decay can be somewhat reduced by felling the timber at the proper season, and at the most suitable age.

Most Suitable Time for Felling Timber.

The proper time for felling is when a tree has attained maturity; the quality of young timber is inferior as regards durability. Maturity is that period in the life of a tree at which the sap-wood bears a small proportion, and the heart-wood is uniform and compact. It is not an easy matter to say when a tree has reached maturity, and it is impossible to lay down any hard and fast rules as to times when trees should be felled, inasmuch as the situation, nature of the soil and other contingencies have

a large influence thereon. It is stated by some authorities that hardwood trees, such as the oak and the chestnut, should not be cut before sixty years of age, and that the average age for felling should be from eighty to ninety years. Other writers consider that one hundred years is the most suitable age for felling oak trees. In the case of soft woods, such as Norway spruce and Scotch pine grown in Norway, from seventy to one hundred years is given as the proper age at which to cut, for ash, larch, and elm, between fifty and ninety years, and between thirty and fifty years for poplars.

As regards the most suitable season for felling, a considerable diversity of opinion seems to exist. It appears, however, that either midsummer or winter are the most appropriate times. Some authorities maintain that the former is preferable, as the leaves are then fully expanded, the flow of the sap ceased, and all such extraneous vegetable matter as is designed for the leaves has been removed from the tree trunk through the agency of the common sap, leaving it in a state of quiescence, and devoid of the principle of germination so easily excited by the presence of heat and moisture, which when existing at the period of felling is the origin of rapid decay, and renders it liable to the attacks of worms.

On the other hand, midwinter is declared by others to be the best season for felling, because the heart-wood of trees felled at that time of the year is not so much affected by moisture, and considered to be the best and the most durable. Britton[1] remarks on this that "as the only peculiar recommendation which that time possesses is the facility which it affords for gradual seasoning, by

[1] *A Treatise on Dry-rot in Timber*, by T. A. Britton. (London: E. & F. N. Spon.)

which timber is rendered less liable to split and get distorted, and slow drying being generally available at any season under shade and shelter, midsummer appears for obvious reasons the most expedient. In general, all the soft woods, such as elm, lime, poplar, willow, should be felled during winter. For some kinds of trees a little after midsummer appears to be decidedly the best time for felling. Alder felled at that time is found to be much more durable; and Ellis observes that beech when cut in the middle of the summer is bitter, and less liable to be worm-eaten, particularly if a gash be cut to let out the sap some time before felling."

In the case of oak trees, the valuable bark is removed, whilst the tree is standing, early in spring, which is the best season. The tree is not felled until the new foliage has been put forth and died. This plan is claimed to also improve the timber and to render the sap-wood as strong and durable as the heart-wood. It is generally considered that all wood becomes harder if barked or worked green.

The age of trees is capable of being deduced from the number of rings of wood that have been deposited around the pith. To make such an estimate it is of course necessary to have an entire section of the stem under observation, but in tropical countries, for the reason given below, this method of computing the age of trees is not to be relied upon. Each of the rings or zones is produced in one year, and in temperate climates, where the growth of the wood is arrested for so many months between the seasons, the zones are distinctly shown, and this marked distinction in the wood produced in the latter part of a former year and that of the first part of the succeeding year continues yearly throughout an extended period.

Definition of the term Wood.

Wooded stems are divisible into two classes, exogenous which enlarge from without and are the most common in cold climates, and endogenous, which grow from within and are most general in warm climates. An exogenous stem always comprises pith, bark, wood, and medullary rays, and each stem has two systems, viz., the cellular or horizontal, and the vascular or longitudinal, the above parts belonging to one or other of these systems.

The term wood is usually held to mean those portions of the vegetable axis that are possessed of a sufficient degree of hardness to afford such resistance and solidity as to admit of use being made of them, for purposes where various degrees of firmness and strength are required. All flowering plants comprise an axis and its appendages, viz., the stem and root, and leaves and flowers. In the case of trees, shrubs and under-shrubs, the axis is designated as woody, whilst in that of herbs it is called herbaceous. In the first instance the stems are permanent, that is to say, they do not die down to the ground annually as they do in the latter. Trees, shrubs, under-shrubs and bushes, are therefore only gradations of magnitude in perennial plants, and woods used for purposes of the arts and manufactures are yielded by them all.

For timber, however, that can be made available for extensive use, bulk and dimensions are required, consequently the greater portion of the woods used are derived from trees.

With the single exception of the pine—which grows to a larger size in cold climates and on mountains at considerable altitudes—both the hardest and the heaviest

woods are produced in the tropical and semi-tropical climates.

Wood consists essentially of vessels and cells, the only solid parts being the coats which form them. The vessels or tracheids form the lungs of the plant, and in these vessels is the sap, the circulation of which through the tree is the source of its existence. On the death of the tree, however, the sap in the wood is liable to produce vegetable decomposition owing to the process of fermentation. Putrefactive fermentation and the subsequent decomposition of vegetable matter is due to albumen, a fact which was first discovered by Kyan, the inventor of the process for preserving wood known as "Kyanizing."

The most common causes of decay in wood are the presence of sap, and being subjected to alternating conditions of wetness and dryness, or to a combination of moisture, heat, and absence of ventilation. There are therefore, three things essential to decay, viz., moisture, warmth, and air. Consequently if wood be buried deep in the ground, or kept under water, it will not decay, neither will wood which is kept perfectly dry be liable to decay. In all other situations, however, unless some substance which will act as an antiseptic or a germicide be employed as a preservative, wood is liable to decay.

Desirability of employing some Process for the Preservation of Wood.

The desirability of employing some efficient process for the preservation of wood is now universally admitted, consequently the importance in the industrial world of such treatment is thoroughly recognized, and the use of preventative solutions is rapidly increasing. The

advancing cost of timber has brought home to the consumer the fact that the only possible offset to this enhanced cost is the use of such preservative methods to prevent, or rather to retard, decay, and thus not only to lengthen the life of wood in all its forms, but also to widen the field of supply by bringing into use a number of less valuable species of timber.

In short, the advancing price of timber and the increasing scarcity of many kinds of wood render the use of some preservative treatment—whereby the life of the wood can be in some cases quadrupled—to protect it from decay advisable in all situations where it is possible to use timber so treated. The desirability of employing such preservative treatment will be more fully realized when it is considered that some 80 to 85 per cent of the wood used is stated to be lost by decay; the ravages of insects, fires, and mechanical destruction accounting for the balance.

In the United States, where a comparatively few years ago the supply of timber seemed all but inexhaustible, the amount of lumber now available hardly meets the ever-increasing demand in a satisfactory manner. This is due to careless lumbering, failure to replant denuded areas, and to the enormous waste caused by forest fire. These remarks are also more or less applicable to other timbered countries.

The magnitude of the lumber industry in the United States may be gauged from the fact that the number of mills is given as 29,648, a total which probably does not include a considerable number of small establishments. As regards the number of men employed, this industry ranks as the third in magnitude, and the reports of the Department of Agiculture for 1913 give the production for one year as being, for softwood

30,526,000,000 ft. board measure, and for hardwood 8,632,000,000 ft. board measure, that is to say, a total of 39,158,000,000 ft. board measure. With the rapidly increasing population, the home demand for timber is naturally rising at a corresponding rate, and in some parts of the country the sources of supply have already become depleted. For instance, in the eastern and middle States the lumber industry is decadent, whilst in the south it is probably now at its zenith. It would appear that the only field for future development lies on the Pacific side, in which region there has of late years been an immense increase of lumber production. Writing on this subject Mr. F. Tiffany observes that high prices having acted as a deterrent and lessened the demand, the immediate fear of absolute exhaustion of the forests is minimized, but that none the less there exists a real need for the conservation of the existing forests and for reafforestation wherever possible.

As a general rule, it may be taken that preservative treatment should only be applied to such woods as are not in themselves resistant to decay, so as to render wood available which otherwise would be useless, and which can be obtained at a low price as compared with durable species. Wood to be treated should be of such a character as to receive impregnation at least through the sap-wood, and when the heart-wood cannot be impregnated it should be in itself resistant to decay. Only perfectly sound timber, free from defects, should be treated.

The beginning of wood preservation, at least on an extensive scale, in this country dates from the initiation and growth of the principal railway systems, which soon created a demand for some efficient process for the preservation of timber, primarily for a variety of uses, but latterly more especially for the treatment of railway ties or

sleepers and crossing timbers. With respect to the latter, the value of an effectual method of preservation will be seen to be of greater value each succeeding year, as the prices of these timbers have increased fully 70 per cent during the last twenty years. That preserving is being more and more extensively resorted to is shown by the fact that owing to the increased demand for creosote alone as an antiseptic for that purpose, both here and in America[1]—to which latter country large exports have been made—the value of this substance has risen so rapidly that within the same period (twenty years) the average price has practically doubled.

Wood preservation on a commercial scale was begun in the United States in 1848, in which year a non-pressure process or steeping plant was operated at Lowell, Mass., by Otis, Allen & Son, the preservative employed being chloride of mercury.

[1] The consumption of coal tar creosote in the United States is given (see *Proceedings American Wood Preservers' Association Bulletin*, 1914) as 108,373,359 gallons, or allowing an estimate for the plants that did not report a total consumption of nearly 116,000,000 gallons for 1913, less than 40 per cent. of which quantity was produced in that country. The imports (see *Wood Preservers' Bulletin*, Oct.–Dec., 1914) amounted to 69,805,678 gallons or equivalent to 64.41 per cent. of the total consumption. These imports were made up as follows: Belgium, 7,675,174 gals.; Germany, 17,947,501, gals.; Netherlands, 7,062,248 gals.; Sweden, 3.600 gals.; England, 22,383,966 gals.; Scotland, 13,581,965 gals.; North America (Canada), 1,151,224 gals. The total imports for 1909 were 39,095,186 gals.; for 1910, 38,213,180 gals.; for 1911, 45,363,012 gals.; and for 1912, 52,298,202 gals. The creosote imported in 1909 (39,095,186 gals.) was valued at 2,221,234 dollars (about 2·8*d.* per gal.), and that in 1913 (69,805,678 gals.) was valued at 3,711,340 dollars (about 2·6*d.* per gal.). The figures for 1914 (see *Pro. Am. Wood Preservers' Association*, 1915) are: Total creosote used, 79,334,606 gallons, of which 51,307,736 gals. was imported.

Early History of the Art of Wood Preservation.

The early history of the preservation of wood by the use of antiseptics is an exceedingly interesting one; unfortunately, however, the space available will only allow of a very brief review of the principal outlines. The art is in all probability one of very great antiquity. It is supposed to have been practised by the ancient Egyptians, and wooden coffins used by them, estimated to be at the very least 2,000 years old, have been found in a good state of preservation. Wooden dowel-pins—probably of tamarisk or shittim wood—are also employed in the stonework of the ancient Egyptian temples, the age of which is undoubtedly over 4,000 years. These latter are in all probability the oldest pieces of wood existing in the world, and are thought to have been treated with some preservative agent, probably bitumen.

Charred wood also has been found in excavations in perfect condition after lying in the ground for some 1,500 years. On the destruction of the Temple of Diana at Ephesus, it was discovered to have been built on charred piles, and at Herculaneum charred wood 2,000 years old was found in good preservation.

Pliny states that the ancients employed garlic boiled in vinegar to preserve wood from the attacks of worms, and that oil of cedar is a specific against worms and decay. He also recommends tar and linseed oil as preservatives. The wooden images of the goddess Diana at Ephesus and Jupiter at Rome were impregnated with olive oil and cedar oil, and the statues of Minerva and Bacchus with oil of spikenard. Cato, Vitruvius and Palladius also give particulars of processes and substances used in their times.

A table was shown at the 1851 exhibition in London

made from the central portion of a charred beam found in an ancient Roman villa near Pompeii, overwhelmed by the eruption of Mount Vesuvius, which almost destroyed the city, A.D. 79. Allowing for the age of the tree when felled this beam, when found in 1835, would have been about 2,000 years old.

Amongst the pioneer investigators into the subject of preservative agents for wood was Johann Glauber, of Carlsbad, Germany, a celebrated chemist in his day. Glauber's experiments were made about 1657, and his process consists in first carbonizing the wood under the action of fire, then coating the surface with tar, and subsequently immersing the wood so treated in pyroligneous acid, or crude acetic acid, which is obtained by the dry distillation of wood.

In the year 1740, a Frenchman named Fagol is stated to have carried out experiments with solutions of alum, sulphate of iron, and various other substances, the wood being immersed in the solutions for several days. Haller, in 1756, proposed the use of vegetable oil as a preservative agent. Jackson, in 1767, suggested a solution of sea salt, with the addition of sulphate of iron and magnesia, alum, lime, and potash were added. Pallas, in 1779, experimented with a process, intended to mineralize the wood, which consisted in first immersing it in a solution of sulphate of iron or copperas (green vitriol) and afterwards in a bath of milk of lime. About the year 1784, Hales proposed steeping the wood to be preserved in a solution of sulphate of copper (blue vitriol) and afterwards coating with oil of tar. Fordyce substituted for the above sulphate of iron, and Congreve suggested the use of creosote as a preservative application. In 1796, Hales suggested that treenails for use in ships should be creosoted.

A Norwegian chemist named Neils Nystrom, in 1800, suggested the use of a solution of sea salt and copperas. The application was to be made with the solution at as high a temperature as possible.

In 1805, it was proposed by Maconochie to impregnate woods of inferior qualities with resinous and oleaginous matters to increase their durability, and to inject the distillation from chips of teak into fir woods.

In 1811, Lukin designed a special stove for impregnating timber with such preservatives as those mentioned above under an increased temperature, but little success attended the experiment. In the latter year also Cadet de Gassicourt saturated various kinds of wood with different vegetable and mineral substances and unguents, metallic salts (iron, tin, etc.).

In 1813, Champy steeped wood in a bath of melted tallow, raised to a temperature of 168°C. (334·4°F.), for from two to three hours.

It occurred to Wade, in 1815, to employ a solution of alum as a preservative. This, however, had been tried many years before and found worse than useless as it caused a rapid decay of the wood so treated. In the same year this experimenter recommended for the preservation of wood the use of oleaginous or resinous matters such as linseed oil and ordinary resin dissolved in a lixivium or lye of caustic alkali, the impregnated wood to be subsequently immersed in a bath of water acidulated with some cheap acid, or with alum in solution. He also suggested the use of sulphate of copper, zinc, or iron, objecting to deliquescent salts on account of their corroding action on metals. A. Boydon, also in the same year, very strongly advocated the boiling of wood, first in lime-water, to correct acidity, and afterwards in a weak solution of glue, to close the pores and render the

growth of vegetation impossible. The glue he also thought might be used by itself, or mixed with lime-water.

In 1816, W. Chapman tried experiments with yellow soap, and in 1817 he conducted a number of further experiments with lime, soap, and alkaline and mineral salts, as preservative agents. One preservative solution which was recommended by this inventor consists of 1 lb. of copper sulphate (blue vitriol) dissolved in 4 gals, of rain-water, and applied hot. Another solution is 1 oz. of corrosive sublimate to a gallon of rain-water applied in a like condition.

In 1822 a patent was obtained by Oxford for what he claimed to be an improved method of preventing the decay of timber. The invention consisted in the extraction of the essential oil of tar by distillation and at the same time saturating it with chlorine gas. With the oil thus obtained suitable proportions of oxide of lead, carbonate of lime and carbon of purified coal tar in a finely disintegrated condition were mixed. This composition is to be applied in thick coatings to the wood to be preserved.

Hancock in 1825 suggested the use of a solution consisting of 1½ lb. of caoutchouc in 3 lb. of essential oil, 9 lb. of tar being afterwards added.

The above mentioned are a few of the processes for the preservation of wood invented during the period that elapsed from the date of Glauber's experiments, many of which would doubtless be found to be more or less effective for the purpose, the chief question being the commercial one as to the possibility of economical application.

In 1831 hydraulic pressure for forcing the preservative agent into the wood was first patented and used by a Frenchman named Bréant.

In 1832 Fontenay suggested the use of the residue to be obtained in the axle boxes of carriages, also from the acid remains of oil, suet, iron, and brass dust, all being melted together. This he termed "metallic soap."

It was during the decade between the years 1830 and 1840 that the most satisfactory results were obtained by the earlier investigators, and indeed several of these processes have survived to the present time and are in successful use in somewhat modified forms. In this regard three methods of preservation may be especially mentioned, viz.: the corrosive sublimate or mercuric chloride ($HgCl_2$) known as the "Kyanizing" process; the dead oil of tar or creosote oil, or creosoting process; and the chloride of zinc ($ZnCl_2$), or "Burnettizing" process.

The first of these processes was invented and patented by Mr. Kyan in 1832. It consists in steeping the wood in a solution of bichloride of mercury or corrosive sublimate, and the preservative effect was originally supposed to be due to the decomposition of the salt ($HgCl_2$) on coming in contact with the albumen of the wood, by which one equivalent of chlorine is evolved, and the salt, which is then converted into protochloride of mercury or calomel ($HgCl$), forms an insoluble compound with the albumen, and prevents, or at any rate largely decreases, its tendency to decomposition. According to Dr. Liebig, however, the corrosive sublimate combines with the lignine or woody fibre and not with the albumen.

The "Kyanizing" process is now less frequently employed owing to the greater cost of the agent and the length of time required to carry out the operation.

In 1835, F. Moll suggested the impregnation of wood with the vapour of creosote oil.

In 1837, Flocton devised a process for the preservation

of wood by saturating it with wood tar and acetate of iron.

Margary also obtained a patent for the application of sulphate of copper to wood for preservative purposes, and a Frenchman named Letellier suggested the immersion of wood in a solution of corrosive sublimate and, after drying, in one of glue, size, etc. He also proposed the use of deuto-chloride of mercury. Margary steeped the wood to be preserved in a solution consisting of 1 lb. of sulphate of copper to 8 gallons of water, leaving the wood in the bath until thoroughly saturated.

In the same year (1837) Bréant, the inventor of the pressure system, obtained a second patent for operating by means of vital suction, and in the following year (1838) a third patent for operating by means of a vacuum created by the introduction of steam into the retort or impregnating cylinder and its subsequent condensation. As a preservative agent he preferably used linseed oil and resin.

John Bethel, in 1838, patented the process wherein the wood to be preserved is impregnated with dead oil of tar or creosote oil, and other bituminous matter containing creosote, also with pyrolignite of iron, which holds more creosote in solution than does any other watery menstruum. The inventor employed hydraulic pressure in closed iron tanks or vessels, from 100 to 150 lb. per square inch being maintained for six to seven hours.

Sir William Burnett in the same year patented the process—known as "Burnettizing"—for saturating the wood with a solution composed of 1½ parts of chloride of zinc ($ZnCl_2$) to 100 parts of water, which was forced into the wood at a pressure of from 125 to 150 lb. per square inch, the air having been previously exhausted from the retort.

A process largely used in France was invented by Boucherie in 1840. The preservative agent employed is sulphate of copper ($CuSO_4$), a solution of which is forced into the wood by gravity. The timber to be treated is set on end covered with a water-tight cap, and the solution, consisting of 1 part of sulphate of copper to 100 parts of water, is delivered into this cap from a tank placed at a considerable height by means of a flexible pipe. The sap of the wood is forced out at the lower end, its place being taken by the solution.

Champy suggested a process consisting of dipping the wood whilst green in melted tallow at a temperature of about 93·3°C. (200°F.). The water and gases being driven out, the melted tallow is said to penetrate into the pores of the wood under atmospheric pressure. A similar process to the above with resin instead of tallow was advocated by Payne.

In 1841 a German chemist named Müenzing suggested the use of chloride of manganese (waste liquor from the manufacture of bleaching powder) as a preventative of dry-rot.

The preliminary steaming of the wood was introduced by Payne in a process patented by him in 1841. The preservative agent employed consists of sulphate of iron, or ferrous sulphate ($FeSO_4$), and muriate of lime. The plant described and used by the inventor comprised a cylinder or retort which does not differ materially from those employed at the present day. Briefly the process consisted in arranging the timber to be treated on a sledge, on which it is kept in position by hoops and chains, and the sledge being arranged to run on rails into a long, cylindrical iron vessel, or retort, the cover or door of which is then screwed on air-tight. Steam is then admitted, through a valve, and the air driven out, after

which a partial vacuum is formed by the introduction of a certain amount of cold solution of sulphate of iron (protosulphate of iron), which is pumped into the retort by means of pumps worked from a steam engine, and the steam in the retort condensed. An air pump is then started to complete the vacuum, the antiseptic solution flowing in as the air is exhausted, and pressure is subsequently applied by means of force pumps worked from the engine so as to fill the pores of the wood. After a few minutes the sulphate of iron solution is allowed to flow out of the retort, the air being readmitted, the retort is again heated with steam and is similarly filled with muriate of lime.

A double decomposition is claimed to take place within the pores of the wood, as the muriatic acid goes over to the iron forming muriate of iron, and the sulphuric acid proceeds to the lime, forming sulphate of lime or gypsum. The latter remains principally in the pores, whilst the muriate of iron pervades the wood generally.

The entire process of preparing the timber, including the filling and emptying of the tank, takes from one to three hours, according to the dimensions of the retort.

Wood subjected to this treatment becomes much heavier, and is claimed to be not only less predisposed to decay, but also less combustible, darker in colour, and proof against dry-rot and the ravages of insects.

The inventor also provides by certain variations of the process, and by the use of some other salts, for staining the light-coloured English woods in a variegated manner, throughout their substance, and thus rendering them more suitable for ornamental furniture. The principal application of the process, however, is for the treatment of timber for use for railway purposes, for building, and for piles.

In 1842 a solution of corrosive sublimate in turpentine, or in oil of tar, was suggested as a preservative by Professor Brande.

In 1843 Parkes proposed to employ caoutchouc dissolved, in sulphur, for application either by brush or by immersion.

Passez, in 1845, also proposed to dissolve caoutchouc in sulphur, and to employ the solution as a paint or to immerse the wood in it.

In 1862 de Lapparent suggested the use of a paint for preventing the growth of fungi, of which the basis is flour of sulphur, linseed oil being employed as an amalgamator. He also favoured the charring of wood. The paint consists of flour of sulphur 200 grammes, linseed oil (common) 135 grammes, and prepared oil of manganese 30 grammes. M. de Lapparent, who was at that time Inspector-General of Timber for the French Navy, proposed the use of this paint on either the ribs of a vessel or underneath the ceiling, and considered that the sulphurous atmosphere developed would tend to destroy the sporules of fungi. This inventor also devised an apparatus for the carbonization of wood with ordinary inflammable coal gas, a device also useful for burning off old paint.

John Cullen, about 1873, patented a composition for the preservation of wood. The invention consists essentially in a composition of coal tar, lime, and charcoal, the latter two ingredients being reduced to an impalpable powder. The above materials having been well mixed and subjected to heat, the wood to be treated is immersed therein, and impregnation may be very materially assisted by the employment of exhaustion and pressure.

In 1875 Hatzfield suggested the use of ferrous tannate, which he claims possesses the advantage of not losing its

protective action in the course of time, and also to be easy to apply. Most woods have saps which contain gummy albuminous matter, and the idea of the inventor is to convert these into insoluble, unalterable compounds by means of soluble ferrous tannate, which becomes converted into insoluble ferric tannate by oxidation, so as to bring about a sort of petrifaction, greatly augmenting the unalterability produced by tannin alone. The tannin liquor may also be used first, the treatment with a ferrous salt being carried out subsequently. The pyrolignite appears to be the most suitable iron salt.

The preceding is a brief chronological outline of the early history of wood preservation by the use of antiseptics or germicides from 1657 up to the latter part of last century. To the various processes devised and used during recent years, and the modern appliances for the preservative treatment of wood, separate chapters are devoted.

CHAPTER II

The Destruction of Wood by Decay and the Ravages of Insects.

Wet-rot—Dry or Sap-rot—Effect of Dry-rot on Health—Molluscan Wood-Borers: The Pholas—The Teredo Navalis or Shipworm—The Xylotrya—The Lepisma—The Sphaeroma—The Limnoria terebrans or Gribble—The Chelura terebrans or Wood-boring Shrimp—The Formica fuliginosa or Black Carpenter Ant—The Formica fusca or Dusky Ant—The Formica flava or Yellow Ant—The Thermite or White Ant—The Red Ant—The Carpenter Bee—Beetles, etc.

Wet-rot and Dry or Sap-rot.

TWO kinds of decay are distinguished: wet-rot and dry or sap-rot. The former, which may on rare occasions occur whilst the tree is standing, takes place where the gases evolved, principally carbonic acid (CO_2) and hydrogen (H), can escape from the tissues of the wood, the sappy portions especially becoming decomposed.[1] The latter, which takes place only in dead wood, occurs in confined places, where the gases evolved, finding it impossible to escape, enter into new combinations and

[1] Baron Liebig defines the following three processes of decomposition: (1) Oxygen in the atmosphere combines with the hydrogen in the fibre, and the oxygen unites with the hydrogen in the fibre, and the oxygen unites with the portion of carbon of the fibre and co-operates as carbonic acid; this process is known as decomposition. (2) The actual decay of wood which takes place when it is brought in contact with rotting substances. (3) Putrefaction, which he holds to arise from the inner decomposition of the wood in itself. It loses its carbon, forms carbonic acid gas, and the fibre, under the influence of the latter, is changed into white dust.

produce fungi, which derive their nourishment from, and thus destroy, the wood.

Wet-rot consists of porous fibres extending from the rot into the trunk of the tree, and is brown in colour, with a disagreeable odour. Wet-rot frequently has white spots of a watery substance; when it has yellowish flames, it is exceptionally dangerous. Referring to fungi, Britton, in his treatise on *Dry-rot in Timber*, says: "A large quantity of the vegetable kingdom consists of plants differing totally from the flowering plants in general structure, having no flowers, and producing no seed properly so called, but propagating by means of minute cellular bodies, called *spores*. These highly organized vegetables are known to botanists as *Cryptogamia*. Fungi are plants in which the fructifying organs are so minute that without the aid of a powerful microscope they cannot be detected. To the naked eye, the fine dust ejected from the plant is the only token of reproduction. This dust, however, is not truly seed, for the word seed supposes the existence of an embryo, and there is no such thing in the reproductive bodies of fungi. The correct term is *spores*, when the seeds are not in a case; *sporidia* when enclosed in cases. The spores or sporidia are placed in or upon the receptacle, which is of very various forms and kinds, but how different soever these may be, it is the essential part of the fungus, and in many cases constitutes the entire plant. That portion of the receptacle in which the reproductive bodies are embedded is called the *hymenium*: it is either external, as in the agaric, where it forms gills; or included, as in the puff-balls. The *pileus* of fungi is the entire head of the plant, not a mere head covering.

"Some naturalists have insisted upon the spontaneous production of fungi, while others maintain that they are produced by seed, which is taken up and supported in the

air until a soil proper for its nourishment is presented, on which being deposited it springs up of various appearances according to the principle of the seed and the nature of the recipient. It is extremely difficult to give a logical definition of what constitutes a fungus. It is not always easy with a cursory observation under the microscope to determine whether some appearances are produced by fungi, insects, or organic disease; experience is the safest guide, and until we acquire that we shall occasionally fail."

A very large number of fungi are known to naturalists: the *Index Fungorum Britannicorum* mentions 2,479 species of British fungi alone. It is obvious, therefore, that the study of this very extensive family of plants is a science in itself, and that any attempt at a detailed account of its arrangement would be outside the scope of this work.

The growth of destructive fungi or the revegetation of timber requires air, light, and moisture. Organic matter, such as timber or dead wood, containing nitrogen, is very susceptible to the action of moisture and varying temperatures, as the nitrogen, not possessing any great affinity for the other elements contained in the wood, favours decomposition or decay. When this decomposition has once set in the germs of cryptogamous plants, possibly deposited in the structure during life by the sap whilst circulating, develop with great rapidity, and help the action of the other causes which produce eremancausis or slow decay.

Figs. 1 and 2 are two views, for which the writer is indebted to Messrs. R. Wade, Sons & Co., Ltd., of a wood-destroying fungus (*Lentinus Lepidus*) growing on a red fir sleeper in South Dakota, U.S., and Fig. 3, reproduced from an illustration given in the Allis-Chalmers Bulletin for

July, 1909, shows the growth of destructive fungus on an untreated white oak sleeper. Fig. 4 shows an

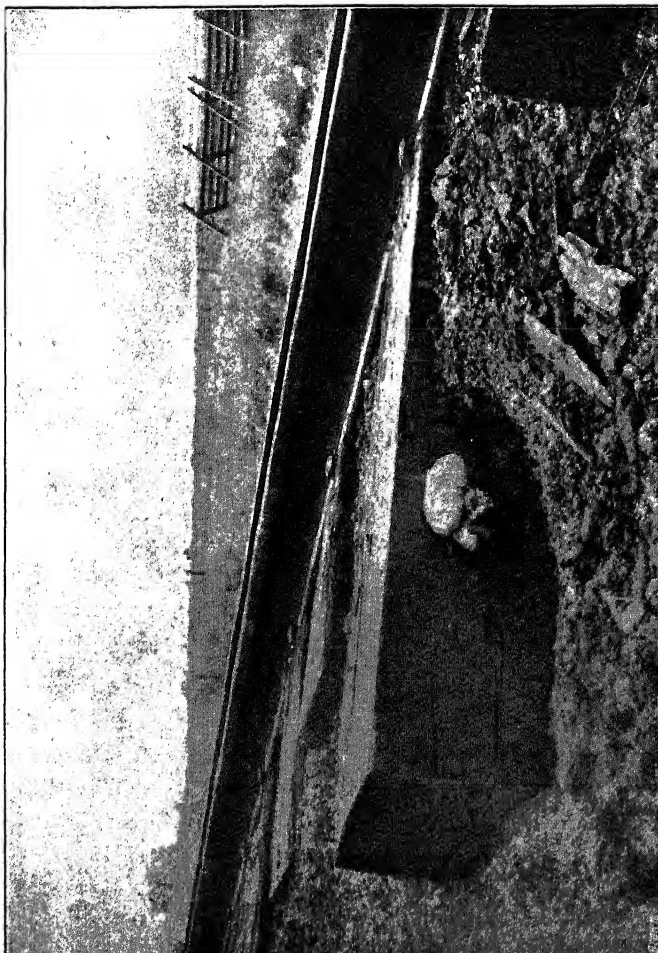

FIG. 1.—View showing wood-destroying fungus (*Lentinus Lepidus*) growing on a red fir tie or sleeper in South Dakota, U.S.A.

untreated cypress wood paving block after twelve years' service.

The fungus which produces dry-rot is, says Britton, of various appearances, differing in accordance with the

FIG. 2.—Enlarged view of fungus shown in Fig. 1.

situation in which it exists. In the earth it is fibrous and perfectly white, ramifying in the form of roots; passing

through substances from the external surfaces, it somewhat differs from that form; here it separates into innumerable small branches. Mr. McWilliam observes: "If the fungi proceed from the slime in the fissures of the

FIG. 3.—View showing growth of destructive fungus on an untreated white oak sleeper.

earth, they are generally very ramous, having round fibres shooting in every direction. If they arise from the roots of trees, their first appearance is something like hoar-frost; but they soon assume mushroom shape."

FIG. 4.—Untreated cypress wood paving block after twelve years' service.

The fungus principally associated with that form of decay known as "dry rot," and one of the most formidable of the tribe of fungi, is the *Merulius lachrymans*, which is thus

described by Dr. Greville: "Whole plant generally resupinate, soft, tender, at first very light, cottony and white. When the veins appear, they are of a fine yellow, orange, or reddish-brown, forming irregular folds, most frequently so arranged as to have the appearance of pores, but never anything like tubes, and distilling, when perfect, drops of water." Hence the term *lachrymans*, from Lat. *lacrymo*, I weep. In the genus *Merulius*, the texture is soft and waxy, and the hymenium is disposed in porous or wavy toothed folds. Berkeley, in his ***Fungology***, gives a description, which resembles Dr. Greville's: "Large, fleshy, but spongy, moist, ferruginous, yellow, arachnoid and velvety beneath, margin tomentose, white, folds ample, porous, and gyroso-dentate."

This fungoid growth insinuates itself between the woody fibres, spreads with great rapidity, and quickly causes the destruction of the wood attacked. The *Merulius lachrymans* does not occur where the wood is exposed to currents of dry air, light, and warmth, and is a specific disease which appears to be peculiar to the woodwork employed in buildings. In the opinion of some experts the *Merulius lachrymans* requires to have the wood prepared for it by the *Coniophora cerebella* or some other acid-producing fungus. Indeed, on a rotting stump a regular sequence of fungi is of common occurrence.

Extensive researches have been made by Richard Falk (*Zeitschrift für Hygiene*, Leipzig, Vol. IV, pp. 478-505) for the Merulius in the forests—where it is abundant, but liable to be overlooked on account of its fructifying in the late autumn and in winter only—with the view of ascertaining whether it is a growth extensively distributed in native timber. The plant was found in a hedge near Breslau, and was plentiful in local timberyards, growing freely beneath the wood-stacks in the sawdust and chips

of wood. It was also found on living fir-trees, and deep down in the moss below the surface of the ground of the roots. Mr. Falk is satisfied from these investigations that the Merulius found in buildings is an entirely distinct species, possessing distinctive peculiarities entitling it to rank as a separate variety. He points out that the rate of growth differs widely in the case of the fungi which destroy timber. For instance, at a temperature of 22° C. (71·6° F.) the Merulius found out of doors grows about 2·5 centimetres in four days, whereas the Tomentella grows as much as 4·4 centimetres in the same time and at the same temperature. It will thus be seen that the rate of growth provides a convenient method of distinguishing between certain of the fungi.

According to the same authority the range of temperature which the different fungi are capable of withstanding divide the species infesting wood into three distinct groups, viz.: those ceasing to grow at a temperature of 26°C. (78·8°F.); those which are capable of resisting a temperature of 34°C. (93·2°F.); and those which are able to withstand a temperature of 40°C. (104°F.). He claims to have proved that heat is fatal to the growth of the dry-rot fungus, and that it is practicable to entirely destroy its vitality by heating the air up to 38°C. (100·4°F.) and maintaining that temperature for four hours, or up to 40°C. (104°F.) for one hour. The Lenzites group of fungi, however, are able to withstand comparatively high degrees of temperature to a remarkable extent.

A fungus which, according to Dr. H. Zikes (*Zeitschrift des oesterreichischen Ingenieur- und Architekten Vereins*, 1903, pp. 145-8), exists in live timber and may continue its destructive action after the tree has been felled and turned into lumber, is the *Polyporus vaporarius*, which, however, is rare. The mycelium is always white, and the

felted network is without the broad water-vessels exhibited by the dry-rot fungus. The growth of this fungus is prevented by the wood being dried before use and proper ventilation provided. Other fungi attacking timber are : *Lenzites sepiaria* and *abistina* on coniferæ, and *Daealea quercina* on oak, which only grow on very damp wood, the organs of fructification only appearing on the surface, and the mycelium occupying the interior of the wood.

A fungi which was formerly found to be extremely destructive to oak-built ships is the *Polyporus hybridus*, of which the following description is given by Berkeley : " White, mycelium thick, forming a dense membrane, or creeping branched strings, hymenium breaking up into areæ, pores long, slender, minute."

The fungi arising from oak timbers are, according to McWilliam, generally in clusters of from three to ten or twelve, while those from fir timber are mostly in single plants ; and these will continue to succeed each other until the wood is quite exhausted.

Britton, in his treatise on *Dry-rot in Timber*, observes : " From the slow progress dry-rot makes in damp situations it appears that excessive damps are inimical to the fungus, for its growth is more rapid in proportion as the situation is less damp, until arrived at that certain degree of moisture which is suited both to its production and vegetation. When further extended to dry situations, its effects are considerably more destructive to the timber on which it subsists : here it is very fibrous, and in part covered with a light-brown membrane, perfectly soft and smooth. It is often of much greater magnitude, projecting from the timber in a white spongeous excrescence, on the surface of which a profuse humidity is frequently observed ; at other times, it consists only of a fibrous and thin-coated

web irregularly on the surface of the wood. Excrescences of a fungiform appearance are often protruded amidst those already described, and are evidences of a very corrupt matter peculiar to the spots whence they spring. According to the situation and matter in which they are produced, they are dry and toughy, or wet, soft, and fleshy, sometimes arising in several fungiforms, each above the other, without any distinction of stem; and when the matter is differently corrupted, it not unfrequently generates the small acrid mushroom."

From the above it will be seen that dry-rot fungi are capable of performing this destructive work with a smaller supply of moisture. These fungi, moreover, possess a quality of remaining in a dormant condition for a considerable time, and are consequently liable to be introduced into buildings with the timber. Their rapid growth under favourable conditions, and the destruction wrought by them upon both new and old buildings, renders the dry-rot fungi especially dangerous.

"Damp is not only a cause of decay, but is essential to it; while, on the other hand, absolute wet, especially at a low temperature, prevents it. In ships this has been particularly remarked, for that part of the hold of a ship which is constantly washed by the bilge-water is never affected with dry-rot. Neither is that side of the planking of a ship's bottom which is next the water found in a state of decay, even when the inside is quite rotten, unless the rot has penetrated quite through the inside."

If wood be kept always wet or always dry, it will last for very long periods. It is on record that a pile was drawn up sound from a bridge over the Danube between Austria and Turkey which had been under water for 1,500 years. A post driven into the ground commences to decay near the surface of the ground. If the post be driven through

water into the ground, it will begin to decay first at the surface of the water. A beam let into a damp wall, will start decaying at the point where the wood enters the wall.

The first appearance of dry-rot externally is in the form of a delicate white vegetation which looks like mildew. Afterwards the fibres of the vegetation become collected together into a more decided form, which has the appearance of hoar-frost Subsequently it rapidly develops the leathery, dense characteristics of the fungus, leaves are formed, it quickly spreads in every direction and over everything, sometimes mounting to a considerable height on the walls. The colour varies, and white, grey, browns of various shades, violet, etc., are amongst the tints shown. If a section of a piece of wood suffering from dry-rot be placed beneath the microscope, white threads spreading and ramifying in every direction through its substance will be seen, the threads being matted together so as to resemble lint and effused over the surface of the wood. In the middle of every large collection is formed a gelatinous substance, which slowly assumes a yellowish hue with a wrinkled, sinuated, porous consistency, and sheds a red-coloured powder upon a white down (which powder is the spores). This is resupinate pilens, the hymenium being upwards, of *Merulius lachrymans* in its perfected and matured condition. For a considerable time before the above condition is arrived at, however, the entire portion of the interior of the diseased wood has perished, the cottony filament has slowly but surely filled up all the sap vessels, and by the time that the fungus makes its appearance externally, the wood is ready to crumble into dust. According to Dr. Haller, seven-eighths of a fungus in full vegetation are completely aqueous. Decomposition may take place without fungus where both timber and situation are always moist.

According to V. Petrin (*Mittheilungen über Gegenstände des Artillerie -und Genie-Wesens*, 1898, p. 79), sap-wood is more liable to be attacked by dry-rot than heart-wood; dry wood is found to offer a greater resistance than wet wood; and timber from trees felled in winter is less liable to be attacked than that from trees felled in summer. Coniferous woods are much more liable to be attacked by the fungus of dry-rot than the woods of leaf-bearing trees. Mr. Petrin strongly recommends, in all cases where timber is required for works of magnitude, a careful inquiry into its origin, and the testing of doubtful wood by so treating samples as to force the growth of the dry-rot bacillus should it be present. The fungus will become visible in from six to eight weeks under favourable conditions to its growth, but with chemicals this time may be reduced by half. Malenkovic (ibid. 1902, p. 1,095) is of the opinion that the dry-rot fungus may propagate itself either by mycelia or by spores, and, in opposition to the opinions expressed by some mycologists, he holds that propagation by spores is incontestably the chief method by which the evil influence of dry-rot is spread. In this opinion he is confirmed by the fact that, whilst the mycelia are very sensitive, and liable to perish immediately when the surroundings are not exactly suitable to their growth, on the contrary the spores are in no way affected by cold, light, currents of air, or the absence of moisture, and, moreover, are distributed by the wind, the agency of animals, etc., in every direction. To enable the mycelium to exist at all in living wood, the sap cells would first have to be destroyed, and, as the fungus has apparently not got the power to effect this, it is impossible for it to grow in the interior of a tree; neither is it capable of existing on the exterior of the tree, as it is extremely susceptible of injury by currents of air. Mr. Malenkovic's researches have corroborated the above

reasons, and he attributes the existence of a contrary opinion by some experts to difficulty of identification. If wood infected with dry-rot be exposed for two or three weeks to currents of air whilst protected from rain, it will be found to contain no trace of the living mycelium. In an experiment made, wood, replaced in its original position after having been subjected to this treatment, showed no trace of the living fungus after the lapse of nine months. The presence of alkalies promotes the development of dry-rot, and the calcium bicarbonate $CaH_2(CO_3)_2$ arising from the hydrate of lime in mortar is probably the most important agent in the development of the spores, which is the reason why the wood nearest to the walls of buildings is always the first to be attacked.

The prevention of dry-rot apparently resolves itself into means for solidifying or coagulating the albumen of the wood. The effect of this process would be, however, to harden the sap-wood, and thus to greatly augment the difficulty of working.

Effect of Dry-rot on Health.

It has been considered by many scientists that the presence of the dry-rot fungus in dwelling houses may be injurious to the health of the occupants. Britton states that "When workmen are employed in buildings which contain dry-rot and when they are working on ground which contains the symptoms of this disease, their health is often affected." In support of this opinion he quotes the statement of a builder that while building some houses at Hampstead his men were never well, and that he afterwards ascertained that the ground was affected with rot. This opinion is also expressed in a book entitled the *Hand-*

book of Hygiene (Pettenkofer and Ziemssen), published in 1894.

Researches and experiments, however, conducted by Dr. Emil Gotschlich (*Zeitschrift für Hygiene*, 1895, p. 502) failed to demonstrate the truth of the above statements. The dry-rot fungus would presumably be capable of operating injuriously upon men or animals in two ways, viz., by a toxic action of the mycelium, the spores, or the gaseous or other emanations; or by the parasitical existence of the fungus in the body itself. No case of illness could be traced to the presence of the fungus in strongly affected houses, nor was the presence of the fungus, subcutaneous injections of brown juice expressed from it, inhalation and injection of the spores, or the supplying of the mycelium as food, found to act injuriously to the health of white mice, rabbits, guinea-pigs and dogs, or to demonstrate in the body or tissues the existence of the fungus propagated by its spores.

It is very difficult to cultivate the fungus artificially, pieces of wood to which the fungus had already attached itself naturally were therefore chiefly made use of, and these were maintained at various temperatures from 12°C. (54°F.) to 37°C. (98°F.). Whenever the temperature approached 29°C. (85°F.) to 35°C. (95°F.) the fungus dried up and shrivelled away. Dr. Gotschlich therefore concludes that this fungus could not exist at blood heat.

The precautions against dry-rot are free access of fresh air, and avoiding contact between the wood and brickwork. Where this is impracticable recourse may be had to the use of antiseptics. When dry-rot is once established, the best, in fact the only, remedy appears to be to subject the infected wood to a temperature fatal to the growth of the dry-rot fungus.

Destruction of Wood by Marine Worms, etc.

A fertile source of destruction of timber, especially in tropical waters, is that by marine worms or shipworms. Eight distinct species of teredines are recognized. The three most destructive of these are the teredo bipenata, teredo fatalis, and the teredo navalis, all three of which are to be found in European waters as well as the equally destructive limnoria terebrans. In fact these pests are active in the waters of both warm and cold climates, although the more so in the former.

The teredo navalis is one of the acephalous mollusca, belonging to the class *lamellibranchiata* of the order conchifera, and of the family of the pholadariæ. The teredo is described by Britton as being of an "elongated vermiform shape, the large anterior part of which constitutes the boring apparatus, and contains the organs of digestion, and the posterior, gradually diminishing in size, those of respiration. The body is covered with a transparent skin, through which the motion of the intestines and other peculiarities are plainly visible. The posterior or tail portion is armed at its extremity with two shells, and has projecting from it a pair of tubular organs, through which the water enters, for the purpose of respiration; this portion is always in the direction of the surface, and apparently in immediate contact with the water, but does not bore. The anterior portion of the animal is that by which it penetrates the wood, being well armed for the purpose by having on each side a pair of strong valves, formed of two pieces perfectly distinct from one another: the larger piece protects the sides and surface of the extremities, and has a shelly structure projecting from the interior, to which the muscles are attached; the smaller piece is more convex, and covers

that part which should be regarded as the anterior surface of boring. This portion of the shell is deeply carniated and seems to constitute the boring apparatus. The shells form an envelope around the external tegument of the animal, which even surrounds the foot or part by which it adheres to the wood. The neck is provided with powerful muscles. The manner in which it appears to perforate the wood is by a rotary motion of the foot, carrying round the shells, and thus making those parts act as an auger, which is kept or retained in connection with the wood by the strong adherence of the foot. The particles of wood removed by this continued action of the foot and the valves are engorged by the animal, for between the junction of the two large shells there is a longitudinal fissure in the foot, which appears to be formed by a fold of this portion of the two sides, thus forming a canal to the oral orifices, and along which the particles of wood bored out are conveyed to the mouth. The mouth, or entrance to the digestive organs, is of funnel shape, and consists of a soft or membraneous surface capable of being enlarged, and leading into an œsophagus which passes backwards towards the dorsal surface of the animal. At or near the termination of the œsophagus there is a glandular organ, the use of which is possibly to secrete a fluid for assisting in the digestion of the wood,[1] and not as has been supposed to act as a solvent, for if such were the case, it would most probably be situated at its commencement instead of at its termination. At a short distance behind this organ are two other large glandular bodies, the use of which may also be to secrete fluid for the purpose of digestion. The œsophagus terminates in a large dilatation,

[1] The more general opinion appears to be that the boring action of the teredo is a mechanical one, although some scientists hold it to be a chemical one effected by an acid secretion.

into which these organs pour their contents; at its posterior end the canal is dilated into a very large elongated sac, which extends backwards to about one-fourth of the length of the whole animal, and is filled with food, while from its anterior, or upper surface, it has an oval, muscular formation, from which the alimentary canal is continued forwards, and, after making a few turns, passes backwards in an almost direct line, on the upper surface of the large sac, again passing backwards and forwards, until it finally arrives at its termination, which it passes round, and then proceeds in a direct line to the anal outlet." By the aid of the miscroscope extremely minute portions of woody fibre have been found in the œsophagus and in the sac. The worm lines the passage in the wood with a hard shell non-adherent to its body and secreted by the external covering. The teredo fits loosely in this shell, and the intermediate space is filled with water, which serves for breathing and forms a current which expels excreted fœtal matter.

In the case of wood recently attacked by the teredo navalis, the signs are scarcely visible on the surface, and it is not until the destruction has proceeded to a considerable extent that it becomes obviously externally apparent. Meantime, however, the timber may be completely honeycombed on the interior, the only external signs being a number of very minute perforations on the surface, usually covered and concealed with slime. The tail of the worm will be found in close proximity to one of these openings, and the head at the end of various turnings and twistings, in many cases over three feet therefrom.

The teredo lays eggs which are washed against timber submerged in the water and to which they become attached, and as soon as hatched the worm immediately

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The teredo lays eggs which are washed against timber submerged in the water and to which they become attached, and as soon as hatched the worm immediately

commences boring. Each individual is in itself capable of propagation.

Three genera of molluscan wood-borers, the pholas (piddock), teredo, and xylotrya, are mentioned by Dr. L. F. Shackell,[1] as infesting the waters round Beaufort, Carolina, U.S., the latter (xylotrya gouldi) being by far the most numerous. Dr. Shackell gives the following characteristics of this borer: "Xylotrya enters a piece of wood while still a very minute bivalve embryo. Once in the wood, this embryo, which has hitherto greatly resembled a microscopic clam, now undergoes a remarkable metamorphosis—the bivalve shell becomes modified to form the boring apparatus, the surface being covered with rows of toothlike protuberances much like a rasp. The body of the borer becomes elongated in proportion to its boring activity; but the posterior end always remains at the site of original entry. From this posterior end project two sensitive muscular tubes, the siphons, which serve not only for the circulation within the borer of sea-water with its suspended food materials, but also for the ejection of macerated wood; for xylotrya swallows through a wide pharynx at the anterior end all the wood that it excavates, and this wood must pass through the alimentary canal before it can be ejected. The opening of the shorter or inhalent siphon is fringed with a number of extremely sensitive tentacles. In xylotrya the longer or exhalant siphon is not provided with tentacles. When necessary the siphons can be withdrawn into the burrow, and the hole at the surface of the wood plugged up with a pair of calcareous pallets."

Experiments were made to test the efficiency of various

[1] "The comparative toxicity of coal tar creosote and creosote distillates and of individual constituents for the marine wood borer xylotrya," *American Wood Preservers' Association*, 1915.

constituents of coal-tar creosote in protecting piling. The experimental work was carried on at the Marine Biological Station of the U.S. Bureau of Fisheries, Beaufort, North Carolina, from July 15 to September 15, 1914. The method of testing adopted was to carefully dissect before each experiment specimens of xylotrya from pine boards which had been exposed to the attacks of the borers for not more than five months, those chosen generally averaging an inch in length; but where there was any considerable variation in size of a number of xylotrya, the latter were so distributed in different groups as to practically equalize any error due to this factor. It was early noted that if specimens of xylotrya were placed in one of the creosote preparations, the most definite objective effect appeared in the siphons. The latter first became insensitive at one or both tips. This was followed by a very peculiar blistering and softening of the tips. The further extension of this degenerative process depended upon the length of time that the xylotrya were in the poison, running often fairly sharply over the distal half of each siphon, or over the entire length of the siphons, or even in exceptional cases over the mantle or body covering, of which the siphons are specialized outgrowths. Observation, moreover, showed that when the siphons in a given specimen were degenerated to any marked degree, the animal itself died within a few hours. This degeneration being the most consistent and accurately observable phenomenon associated with the action of the creosote preparations, was made the basis of comparison in the determination of their relative toxic values. The following is a summary of the results of the numerous tests made by Dr. Shackell: "(1) The toxicity of creosote fractions diminishes with rise of boiling point; the toxicity of creosote itself lies between that of the lowest and highest

boiling fractions. (2) The loss of volatile constituents reduces the toxicity of creosote and of its fractions. (3) The light oils of creosote are very toxic even in the extremely slight proportions in which they are soluble in sea-water. (4) Napthalene and anthracene are practically non-toxic for xylotrya. (5) The tar acids are extremely toxic for xylotrya, alphanaphthol being many times more poisonous than phenol."

Mr. E. S. Christian[1] says that he has frequently seen specimens of xylotrya and other teredo 3 ft. in length and ⅝ of an inch in diameter, although the more destructive borer is much smaller and by far more numerous. He mentions that timber, in a pier just below the mouth of the James river, treated with 12 lb. of dead oil of tar per cubic foot withstood the attacks of marine borers for thirty-two years whilst timber not creosoted was destroyed in the same water in two years. This writer also mentions that three sections were taken from a creosoted pile between the high water and the mud lines and sent to three chemists to determine the quantity and which fractions of the oil remained, and that it was found that after thirty years' service there remained 10·5 of the original 12 lb. of oil, and that of this quantity 55 per cent. was naphthalene. The specification of the oil used for impregnation was as follows: "It must be distilled from the coal tar derived from Newcastle coal, and must be of a greenish yellow colour when liquefied. It shall not contain any water. Not over 8 per cent. of tar acids. Not less than 60 per cent. of naphthalene. Not less than 20 per cent. of anthracene and anthracene oil. Not less than 5 per cent. shall remain in the flask after it has been heated to a temperature of 320°C. (608°F.)."

1 "Destruction of timber by marine borers," *American Wood Preservers' Association*, January, 1915.

Mr. Christian states that during his thirty-two years' experience in the handling of creosoted timber he does not know of a single instance of failure provided the necessary quantity of oil of standard quality was injected into the timber.

Mr. A. L. Howard, writing on "African Mahogany" (*Timber Trades Journal*, March 28, 1914), mentions a teredo worm 22 ins. in length by upwards of $\frac{3}{4}$ in. in girth found in one of the logs from Cape Lopez. This authority states that the teredo bores at the rate of more than one inch per hour, and he instances as a proof of the activity of these worms that a board 6 ft. long by 20 ins. wide was found to be perforated by more than seventy holes.

A worm very destructive to timber submerged in sea water in the East Indies is the lepisma. At Charleston, U.S., the sphaeroma is found to attack in conjunction with the limnoria and xylotrya.

The limnoria terebrans, a mollusc of the leach (asselotes) family, known as the gribble, is plentiful in British waters, and is extremely destructive to woodwork under water. This crustacean is very small in size, being only about $\frac{1}{8}$ in. in length, and somewhat resembles the woodlouse. The gribble attacks timber below water in vast hordes and in a comparatively short space of time completely honeycombs the surface of the wood with holes about $\frac{1}{16}$ in. in diameter. Soft wood is preferred by this pest, but it is quite able to operate upon the hardest, teak and greenheart being reputed the only woods immune to its attacks. The limnoria is supposed by some to bore wood by means of a kind of dissolvent liquor produced from its own juices, but at least one authority considers that it uses its mandibles for the purpose.

The limnoria operating in pure salt water is capable of perforating wood at the rate of about $\frac{1}{8}$ in. per month. The animal cannot live in fresh water. The female is

about three times the size of the male, and possesses a pouch in which first the eggs and afterwards the young—generally about seven—are carried.

The chelura terebrans or wood-boring shrimp is another crustacean almost as destructive to wood as the teredo. This animal bores holes or tunnels in the wood in an oblique direction and very near the surface, the thin walls becoming soon broken away, when it constructs a fresh one, and so on, so that a rapid destruction of the wood is thus effected. The boring is performed by a kind of rasp with which the animal is provided; flattened appendages at the tail serve for the purpose of clearing the bore-hole of the powdered wood. The chelura swims on its back and clings to the wood, into which it bores with the legs proceeding from the thorax. Placed on dry land, it is capable of jumping to a considerable height.

Many years ago the chelura was found to have been very injurious to the piles in the harbour of Kingstown, and in a very interesting paper read before the Institution of Civil Engineers in Ireland in 1847 by Mr. Mullins, a description of the chelura and its ravages is given.

The martesia striata is a variety of borer well known in tropical waters and attacking the tropical hardwoods. This animal is said to have lately made its appearance in the sub-tropical waters of the Gulf of Mexico.

Woods which resist Seaworms.

Britton.

Australia, Western.—Jarrah, beef-wood, tuart.

Bahama.—Stopper-wood.

Brazil.—Sicupira, greenheart.

British Guiana.—Cabacalli, greenheart, kakarilly, silver-balli (yellow).

Ceylon.—Halmalille, palmyra, thect-kha, neem.

Demerara.—Bullet, greenheart (purple heartwood), sabicu.

India.—Malabar teak, sissoo, morung sál, dabu, thankya, ilupé, anan, angeli, may-tobek (teak resists the teredo, but is not proof against barnacles).

Jamaica.—Greenheart.

North America.—Locust.

Sierra Leone.—African oak, or tortosa.

South America.—Santa Maria wood.

Philippine Islands.—Malacintud, barnaba, palmabrava.

Tasmania.—Blue gum.

West Indies.—Lignum vitæ.

The turpentine tree of Australia and the sneeze wood of Cape Colony are also said to be proof against the shipworm.

The preceding list mentions jarrah as being one of the woods supposed to offer more or less resistance to the action of marine worms, and the experience of several engineers has demonstrated that it is certainly superior for sea-work to karri.

It may here be observed that jarrah and karri woods are so similar in appearance that it is almost impossible to distinguish the one from the other by sight, and it is said that the only way to make sure of their identity is to burn small pieces, jarrah yielding a black ash and karri a white one.

With regard to the ability of jarrah to resist the action of the teredo or shipworm, Mr. W. Matthews (*Proceedings Inst. C.E.*, Vol. cxxv, pp. 264-5) states that the experience of his firm has been that there was no timber and no preservative that was proof against the ravages of this worm in some tropical waters. He also mentions that in the case of a temporary jetty put up by him to land materials for the works at Colombo, and constructed of Baltic fir creosoted with 12 lbs. to 14 lbs. of oil per cubic foot, it was completely riddled with teredo in two years,

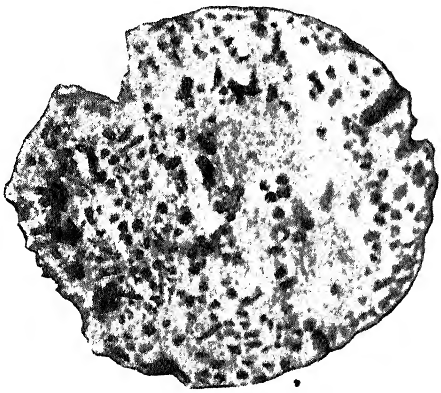


FIG. 5.—Section of untreated oak pile destroyed by the teredo navalis.

and had to be rebuilt. That creosote was not a preventative where the worm was very active he considers to have been proved by the fact that in many of the holes, in some of which the finger could be put in and turned round, creosote could be smelt.

Sir Guilford Molesworth (ibid. p. 272) confirms what Mr. Matthews says with regard to the action of the teredo. He had put down some jarrah in a temporary jetty at Colombo, and found that in less than two years it was thoroughly honeycombed. In some localities jarrah might, he thought, be capable of withstanding that insect, where its action was less active, such as possibly on the coast of Australia. Dr. E. L. Corthell (ibid. p. 273) says that the presence of fresh water, specially muddy water, in sediment bearing rivers of the Gulf of Mexico, made the ravages of the teredo much less than at

FIG. 6.—Section of untreated oak pile, showing the ravages caused by the teredo navalis after two years' service.

points where such conditions did not exist; and at such exposed points a charge of 16 to 18 lbs. of creosote per

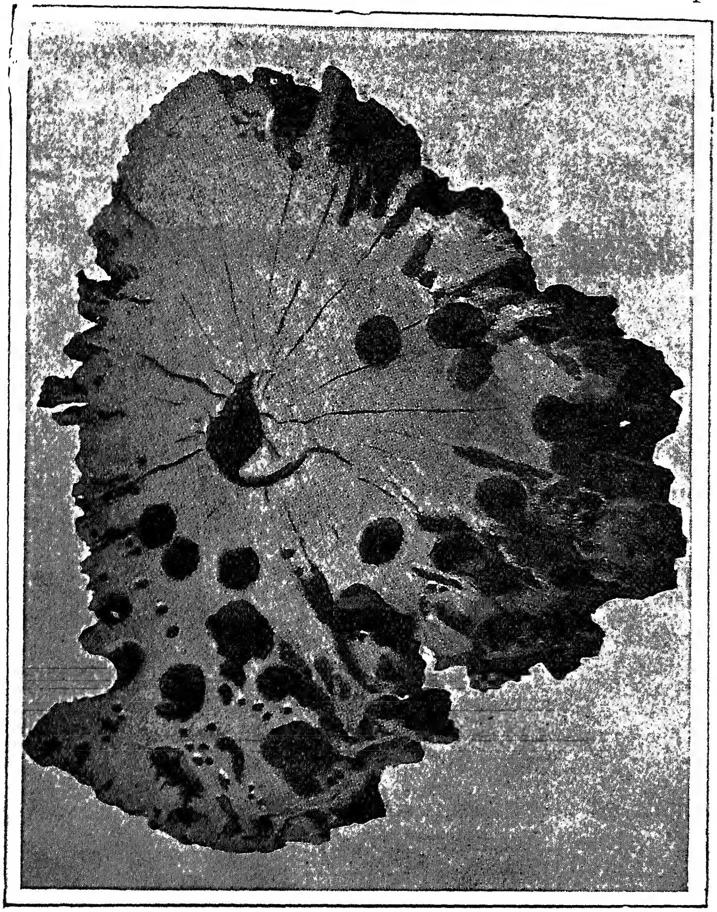


FIG. 7.—Section of untreated oak pile after about three years' service in the water near the mouth of the Aascagoula river.

cubic foot had been found generally sufficient to extend the life of the timber from about two years to an average of fifteen years.

Mr. Howard F. Weiss, in an article entitled "A Teredo-Proof Wood" (*Eng. News*, New York, February 5, 1914), states that the Australian turpentine tree, *syncarpia laurifolia*, is considered by the authorities of New South Wales as being the only timber that they dare drive unsheathed in shipworm-infected water. It is, however, mentioned that it is always specified that piles of this species of timber must be driven with the bark on. The

FIG. 8.—Block of untreated poplar wood after exposure in teredo water for about one year.

opinions of special government investigators who were employed to determine the value of the turpentine tree for the above purpose are quoted by the author.

Figs. 5 and 6 (Allis-Chalmers Company Bulletin No. 1,439) and Fig. 7 (*Business Man's Magazine*) show sections of untreated oak piles destroyed by the ravages of the teredo navalis, fig. 6 after only two years' service and fig. 7 after being about three years in the water near the mouth of the Aascagoula river. Some of the holes in

this section are three-quarters of an inch in diameter. Fig. 8 shows a block of untreated poplar wood which has been exposed in teredo water for about one year. The teredo usually, but not invariably, bores in the direction of the grain of the wood.

Destruction of Wood by Ants.

Three species of that order of ant known as hymenoptera are said to destroy wood, viz., the formica fuliginosa, the formica fusca, and the formica flava. The first of these, commonly called the black carpenter ant, preferably attacks hard and tough woods. The second and third, known respectively as the dusky ant and the yellow ant, usually select soft woods.

The termite or white ant, a family of insects belonging to the order *Neuroptera* (Scorpion flies, etc.), comprises numerous species all of which are intensely destructive to wood in most countries within the tropics. The termite will bore into a piece of wood and destroy everything except a shell not thicker than a sheet of brown paper, whilst externally the wood appears to be in perfect condition. This operation they will perform on the roof timbers and other woodwork in houses, furniture, etc. The popular name of *white ant* is derived from the fact that the insects live together in vast colonies, and in a number of their habits greatly resemble true ants.

Two species of white ants only are known to exist in Europe, the *termes lucifugus*, and the *termes rucifollis*. These are quite as destructive, however, as their tropical brethren, the first having a preference for oak and fir, whilst the second prefers olive and similar woods.

The termite or white ant is an insect which reproduces with extraordinary rapidity, and which grows exceedingly

fast. White ants will attack wood used for any purpose, and in a short time wood so attacked will absolutely teem with the pest, with most destructive results. In India the white ant is a source of destruction which in the case of railway sleepers, telegraph poles, etc., demands serious notice, and there, and in other countries where this insect is found, beams, joists, floor-boards, posts, gates, fencing, furniture, in fact all forms of woodwork, are liable to their undesirable and injurious attention.

Some woods are by nature immune from the attacks of these insects, such a wood is the sepe of the West Indies, which is light, resembling the English elm, and is impregnated with a bitter principle which protects it. The majority of woods employed, however, must be artificially protected from the ravages of the white ant by impregnation with some suitable antiseptic such as creosote. A large number of patent and proprietary preservative preparations are also claimed to be effective deterrents, and for woodwork placed in situations where the smell of creosote or some of the other preservatives would be found objectionable, several of the above could be advantageously employed.

The red ant of Batavia is likewise very destructive to wood. This ant contains formic acid and a peculiar resinous oil.

The following table gives a list of woods said to be capable of resisting for a long time, in some cases altogether, the attacks of termites or white ants.

Ant-resisting Woods.

Britton, Etc.

America.—Butternut, pitch pine. (Pitch pine is sometimes attacked.)

Australia, Western.—Jarrah.

Borneo.—Bilian.

Brazil.—The sicupira, assú, sicupira meirim or verdadeiro, sicupira scari, oiticira, gararoba, paó saulo, sapucaia, paó ferro, and imberiba, resist the white ant, *except* in the sap-wood. The angelim amargozo, araroba, pitia, cocâo bordâo de velha, ameira de sertao, parshiba, cedro, louro cheiroso, and louroti, resist the white ant, even in the sap-wood.

Cape Colony.—Sneeze wood.

Ceylon.—Ebony, ironwood, palmyra, jack, gal-mendora, paloo, cohambe.

Demerara.—Greenheart.

Guiana, British.—Determa, cabacalli, kakatilly.

India.—Cedar, sâl, neem, kara mardá, sandal, erul, nux vomica, thetgan, teak. (Ants will bore through teak to get at yellow pine.)

Indies, West.—Bullet wood, lignum vitæ, quassia wood.

Pernambuco (*Brazil*).—Macaranduba (red), barubú (purple), mangabevia de viado.

Philippine Islands.—Molave, panao.

Tasmania.—Huon pine.

Trinidad.—Sepe.

The Carpenter Bee.

The carpenter bee is found in the northern part of the island of Ceylon; in the southern portion the bee is absent, but a small beetle (*Longicornes* or coco-nut beetle) and the porcupine are both destructive to timber, principally to the young palm trees. The carpenter bee is also present in France and in North America, etc.

The carpenter bee is a genus of insect belonging to the same order as the honey bee, *hymenoptera*, of which there

are numerous species, none of which have, however, as yet been found on the British Islands.

The carpenter bee bores holes in timber to a depth of several inches, using his mandibles for the purpose, with the object of forming a nest in which to deposit eggs, each of which is placed in a cell formed by a partition made of sawdust agglutinated by the bee.

Beetles.

Household furniture in this country is liable to be destroyed by the attacks to several species of beetles. Professor Westwood mentions three belonging to the family of *Ptinidæ*, which are known under the systematic names of *Ptilinus pectinicornis*, *Anobium striatum*, and *Anobium tessellatum*.

In the perfect state, the insects of the genus *Anobium* are well known under the name of the "deathwatch." This insect is most injurious in libraries, the grub burrowing through entire volumes, feeding upon the paper, more especially the pasted backs of books.

These beetles are of small size and cylindrical in form. They are partial to old wood, and capable of making a complete wreck of old wooden furniture, carvings, etc. The only remedy possible is saturation with some obnoxious fluid. Strong infusion of colocynth and quassia, spirits of turpentine, juice of green walnuts, pyroligneous acid, are amongst the preventatives recommended. About the best remedy appears to be corrosive sublimate dissolved in spirits of wine. In the case of books, fumigation may be resorted to.

CHAPTER III

Seasoning or Drying Wood.

Natural or Air Seasoning or Drying—Water Seasoning—Seasoning by Steam—Artificial Seasoning or Drying by Heat—Drying or Seasoning by Positive Air Circulation—Drying or Seasoning by Natural Air Circulation—Drying or Seasoning by Oxygen—Drying or Seasoning by Smoke—Drying or Seasoning by Scorching or Charring—Drying or Seasoning by Electricity—Effect of Time on the Strength of Wood—Effect of Moisture on the Strength of Wood.

THE object of seasoning wood is to effect the expulsion, or the drying up of the sap which is left in it after felling, which would otherwise be liable, as before mentioned, to putrefy and cause decay. The moisture content of wood before subjecting it to preservative treatment should be reduced to not more than 20 per cent. of its oven dry weight, or to a constant weight basis. One result of seasoning wood is a reduction in weight. According to Tredgold timber is seasoned when it has lost one-fifth of its original weight, and is then fit for carpenters' work and ordinary uses, and is dry and suitable for joiners' work and framing when the loss of weight reaches one-third. The nature of the wood and its condition before seasoning must, however, govern the exact loss of weight during the seasoning process. Before being cut into scantlings, timber should be well seasoned; after conversion it should be left as long as practicable so as to admit of the seasoning being carried on as far as possible before being painted or coated

with other protective composition, or subjected to any preservative treatment.

During the process of seasoning or drying wood there is a shrinkage in its volume, which usually commences as soon as a considerable amount of the water has been evaporated. The shrinkage is nearly twice as great tangentially as radially. The longitudinal shrinkage is so small that it may practically be disregarded.

Natural or Air Seasoning.

Broadly, natural or air seasoning is effected by so stacking the timber that the air has free access to circulate round each individual piece, whilst protected from the damp rising from the ground by means of bearers, and from the rain, sun, draughts, and high winds, by a roof. It should be borne in mind that the great desideratum is to effect a regular drying of the timber, as any irregularity will result in splitting. The yard where the timber is stacked should be in the open and so situated that the prevailing winds will strike it freely. It should not be located near any large body of water, or in a low and humid situation, and should be well drained and preferably be paved; in any case, however, it should be entirely free from vegetation. The bearers should be at least a foot in height from the ground level, should be thoroughly damp-proof, and be laid perfectly level and out of winding. The latter is most important to prevent the timber from being given a lasting twist. A permanent roof is desirable, but where this does not exist, each timber stack may be provided with a temporary roof.

It is generally advisable to remove all outer bark before seasoning, and also as much of the inner bark as practicable. No strips of bark more than one inch in width and about six inches in length should in any case be left on.

Logs are preferably stacked with their butts outwards, and the inner ends may be slightly raised so as to facilitate their removal, and packing pieces should be inserted between the tiers of logs, so that by removing these packing pieces the removal of any desired log can be effected.

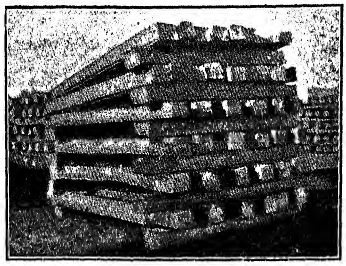


FIG. 9.—Convenient method of piling or stacking sleepers with roof.

It is a usual plan to lay boards flat with pieces of dry wood about 1 in. × 3 in. between them, and should any of the boards show any inclination to warp, they should be so fixed or weighted down as to render it impossible for them to start twisting. Boards are, however, often stacked vertically, or at a steep incline, and another method is to place them on edge in a dry, cool shed fitted up with horizontal beams and vertically arranged iron bars, which latter serve to prevent the boards from tilting over.

FIG. 10.—Open crib method of piling or stacking sleepers.

The storage of lumber naturally must largely depend on the arrangement of plant and the method of stacking or piling the timber. According to American practice, the best yards are laid out so that the length is about four to five times the width, and the tracks from 50 ft. to 65 ft. from centre to centre. A very convenient form of piling or stack-

ing ties or sleepers is shown in fig. 9. Two sleepers are first laid on the ground to act as sills, next a row is placed crosswise on the top of these at equal distance apart. This can be continued upward as shown, the uppermost row of sleepers being arranged slanting so as to form a roof and throw off the rain. The pile or stack so arranged permits of a good air circulation and is convenient for handling. Fig. 10 shows what is known in the U.S. as an open-crib pile.

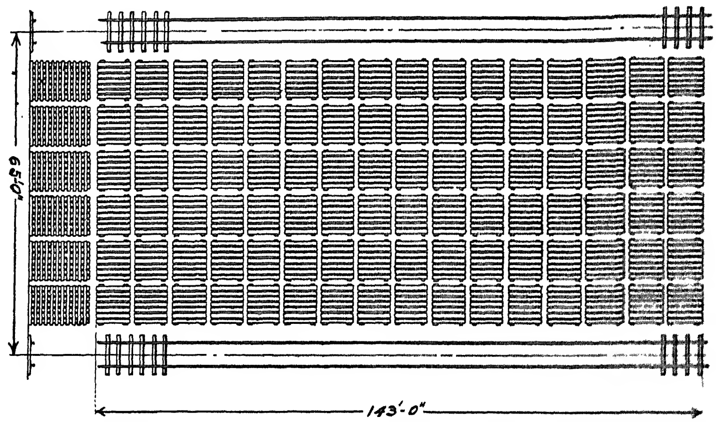


FIG. 11.—Diagram showing in plan and side elevation one section of stacks of ties or sleepers piled 16 × 6.

Fig. 11 shows a section of piles, stacks of ties or sleepers piled 16 × 6, making ninety-six piles of ninety-nine each, which is equal to 9,504 sleepers per section. Each section requires a space of 65 ft. from centre to centre of the tracks, by 143 ft. in length, which is equal to ·67 square feet of land per tie or sleeper.

According to data given by the Allis-Chalmers Company, to whom the author is indebted for the above illustrations, when estimating on total yardage required for buildings, loading platform, tracks, etc., it is safe

to allow about 1·57 square feet of land for each tie or sleeper that is air seasoned. In the piling of lumber 24·27 ties should be allowed for each 1,000 feet of lumber.

The piling or stacking of any wood must depend upon climatic conditions: for instance, in very hot, dry climates the piles of ties or lumber should be arranged to prevent warping. In warm, humid atmospheres where the rainfall is heavy, the piles should be arranged to shed or throw off water.

During natural, or air, seasoning timber should be turned at intervals so as to secure the same amount of drying all round the balks. The length of time required varies according to the size of the timber, the nature of the wood, and to the condition in which it was before commencing the seasoning operation. Air seasoning is also largely dependent on climatic conditions. The approximate time required for seasoning timber when protected from wind and weather is given by Laslett as follows:—

	Oak. Months.	Fir. Months.
Pieces 24 in. sq. and upwards require about .	26	13
" under 24 in. to 20 in. require about .	22	11
" 20 16 " " .	18	9
" 16 12 " " .	14	7
" 12 8 " " .	10	5
" 8 4 " " .	6	3

The time taken by planks will be from one-half to two-thirds of the time given above in accordance with their thickness. It is undesirable to keep timber much longer than the periods mentioned, as if this be done the fine shakes which show upon the surface in seasoning will open out deeper and wider, and may even render the logs unfit for conversion.

In the open, the time required for air seasoning will be two-sevenths longer than under cover.

REPORT COVERING TESTS FOR AIR-SEASONING
6″ × 8″ × 8′ RED OAK TIES

MADISON, ILL. FEBRUARY TO DECEMBER, 1914 (in pounds).
(L. B. MOSES, *Proc. Amer. Wood Preservers' Association*, 1915.)

Tie No.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	200	195	190	182	175	168	163	166	163	165	173
2	195	190	187	178	169	163	157	162	158	162	170
3	166	156	158	150	144	137	133	135	132	135	142
4	172	168	165	156	147	141	136	142	138	140	150
5	176	169	164	155	148	142	137	141	136	140	146
6	184	178	172	162	155	147	143	145	143	145	153
7	149	145	141	133	125	119	114	118	115	116	125
8	155	150	146	137	130	123	118	123	116	122	129

NOTE.—All these ties were green February 6, and it will be seen from the table reached their low point on August 6, after six months' air seasoning.

According to a report made by a committee of the "American Wood Preservers' Association" at a recent meeting (1915) the following periods are required for air seasoning: "Hardwood track ties should be given a minimum of eight months' seasoning, and should preferably be seasoned twelve months; yellow pine, if seasoned in the south, four to six months; hemlock, tamarack, and jack pine twelve months. Over-seasoning may prove detrimental with some species. Practically all woods can be air seasoned, except in low humid locations. Gum is an exception, unless air seasoned under favourable conditions. Both gum and beech should be seasoned only in very open piles, and watched carefully for dry-rot. 'Bluing' of sap-pine during seasoning is not necessarily an indication of decay.

"A determination of whether wood is sufficiently air seasoned for efficient treatment may be based on moisture extraction from borings which should show an average of not over 20 per cent. moisture in relation to the oven dry weight of the wood; or if the above moisture determination cannot be made, season to a constant weight. Consideration may be given to a new Troemroid Scalometer device for determining the moisture content of wood. In some cases it is advisable to make local experiments to determine the weights at which timber treats best."

According to Wm. A. Fisher,[1] engineer to the Atlantic Coast Line, the practice of that company is to conduct seasoning tests by weighing until a constant weight is reached. It has been found that all heart long-leaf pine, short-leaf and loblolly pine (minimum of 3 in. of heart-wood on each 9-inch face) ties, take about four months to season. All cross-ties are stacked in the yard in the 8 × 1 fashion, 100 ties to the stack. Sap-pine switch ties are also found to take four months, and losses of from 14 to 19 lb. per tie in the first two or three weeks are quite common.

The following are the shrinkages in dimensions caused by seasoning for the woods given:

	Inches.	Inches.
American white pine	12	to 11⅞
Canadian cedar	14	,, 13¼
Elm	11	,, 10¾
Northern pitch pine	10 × 10	,, 9¾ × 9¾
,, yellow pine	18	,, 17⅞
Oak (British)	12	,, 11⅝
Spruce	8½	,, 8⅜
Southern pitch pine	18⅜	,, 18¼

[1] *Proceedings American Wood Preservers' Association*, 1915.

Comparative Weight of Green and Seasoned Wood.

	Weight per Cubic Foot.			
	Green.		Seasoned.	
	lb.	oz.	lb.	oz.
Ash	58	3	50	0
Beech	60	0	53	6
Cedar	32	0	28	4
Oak (British)	71	10	43	8
Pine (American)	44	12	30	0
Riga fir	48	12	35	8

Loss of Weight due to Seasoning

American yellow pine	18 to 27 per cent.
Elm	about 40 ,, ,,
Larch	16 to 25 ,, ,,
Mahogany	16 ,, 25 ,, ,,
Oak (British)	16 ,, 30 ,, ,,
Red pine	12 ,, 25 ,, ,,

Water Seasoning.

In cases where time is wanting for the gradual or slow drying of timber by exposure to the air, water seasoning may be resorted to, and it is under these conditions considered by many to be the most advantageous method to employ, more especially for sappy wood.

The sap in wood is of greater density than pure water, owing to the various matters which it holds in suspension. The sap is, moreover, enclosed in fibres or channels which are permeable at the ends. If the water in which the wood is immersed is flowing or even changing periodically, the water will expel the sap and will in a certain time occupy a large portion, if not the whole, of the place formerly occupied by this sap, which will have taken with it the fermenting principle with which it is

charged. It follows from this that timber subjected to water seasoning should be much less susceptible of fermentation than that which has been dried by air seasoning only. Pure water, moreover, is much more quickly and easily evaporated than that charged with certain principles, consequently steeped timber will dry in less time than the other.

It should be observed that timber which is subjected to immersion in either cold or hot water is liable to the substance of the wood becoming dissolved, and will consequently be lighter. Wood that has been treated by water seasoning, even when most carefully carried out, is after the dissolution of a certain soluble part by the water, and it has been subsequently dried, said to become brittle. It is, however, very durable.

To effect the seasoning of timber by water, it is totally immersed and held down by chains, directly after being felled. The timber is kept under water for about fourteen days, by which time the greater portion of the sap is washed out; it is then removed and dried under free access of air, being turned daily.

It is essential in water seasoning that the timber should be completely submerged, as otherwise, where only partially covered, injury will occur along the water-line. Care should also be taken that timber treated in this manner be completely dried before being used. If the timber be cut up and used before it is thoroughly dried, it will shortly be attacked by dry-rot.

Water-seasoned timber is not so liable to warp and crack as when air seasoned, but it becomes, as already mentioned, brittle, and unsuitable for use where strength and elasticity are essential.

Seasoning by immersion in salt water renders wood harder, heavier, and more durable; there is, however,

always a tendency in wood so treated to reabsorb moisture, which renders it unfit for general building purposes.

The use of boiling water hastens the seasoning process, and timber treated in this manner does not shrink so much, but its strength and elasticity is decreased, and the operation is an expensive one. The time occupied depends upon the dimensions and on the density of the timber, and upon various other circumstances. A rule given is to allow one hour for each inch in thickness.

Seasoning by Steaming.

Much the same effect is produced by steaming the timber as results from immersion in hot water, the wood, however, being said to dry more quickly. Both the boiling and steaming processes undoubtedly tend to remove the ferment spores, and are held by some experts to prevent the wood from being attacked by dry-rot.

An early experimenter in the seasoning of wood by steaming was a German chemist named Newmann, and a method of seasoning wood by the extraction of the sap was the subject of a patent obtained by J. S. Langton as long ago as 1825. It consists essentially in placing the timber in vertical iron cylinders standing in a cistern partly full of water. The cylinders are then closed at their upper ends, and the water in the cistern being heated the steam is used to form a partial vacuum. The sap in the wood being in this manner relieved from atmospheric pressure, oozes or sweats from the wood, and, becoming vaporized, is carried away through a pipe provided for that purpose. The time required to carry out the operation of effecting the entire extraction of the sap is about ten weeks. This process has now practically gone out of use.

In a report to the American Wood Preservers' Association, made in 1914, it is stated that a certain manufacturing concern has for several years been exploiting a process for the steaming of timber and other forms of wood, preliminary to kiln drying or air seasoning. The apparatus consists of a steel cylinder, six to ten feet in diameter, permanently closed at one end and fitted at the other end with a quick opening and closing door. The cylinder may be any length desired. The manufacturers of the apparatus claim, among other things, that the employment of steam under pressure on lumber, green from the saw, renders the lumber susceptible of thorough kiln drying in an ordinary kiln, or air drying in the open, in one-third less time than ordinarily required when not steamed, and it aoes not impair the strength of the wood. This method of seasoning lumber has been practised for nearly seven years, and seems to work very satisfactorily. The apparatus has been installed by a number of leading manufacturers in various places.

A later report (1915) to the same Association points out that it has been demonstrated by recent tests (Bulletin No. 168, American Railway Engineering Association) that there is a material reduction in strength of Douglas fir piling from steaming. This wood appears to offer a special problem in seasoning. It is also stated that in seasoning by steaming the pressure should at no time exceed twenty pounds per square inch, nor the oil temperature, when seasoning by boiling is used, exceed 104·5°C (220°F).

A system of steam seasoning introduced by the Steam King Co., which is known as the S.K. process, is adaptable to almost any kiln actually working under any of the ordinary methods.

This process consists essentially in the use of steam

that has been treated in a special gasificator in order to completely dry it, transform it into a gas, and raise it to a high temperature. It is contended by the inventors that, as this very highly superheated steam acquires new properties and a peculiar avidity for moisture, it becomes a very convenient and desirable medium for the purpose of drying the wood in the chamber.

The requisite supply of steam is obtained either from existing boilers, if available, or from a small boiler, preferably of the vertical type, located in close proximity to the apparatus, the pressure required being anything over 30 lb. per sq. in. The amount of steam required is not large, being about 1 lb. per hour for each cubic yard capacity of the kiln in order to maintain a temperature of from 49°C. to 54°C. (120° to 130°F.), no external air being admitted. Thus for an ordinary-sized kiln about 2 cwts. of coke per day should be sufficient fuel for raising the required supply of steam.

According to the inventors, as the unsaturated steam comes into direct contact with the timber in the kiln, not only is the latent heat of the steam entirely available for the purpose of evaporating the moisture from the wood, but also the latent heat of water comes into play. Thus to evaporate 5 lb. of moisture they claim that only 1 lb. of unsaturated steam will be required.

In operation with, say, planks, these are stacked with 1 in. space between them, the superheated steam being allowed to issue from nozzles fixed on a steam pipe mounted on one of the sides of the kiln, and the moisture is allowed to escape by the opposite side in order to force the gasified steam to pass through the entire width of the kiln and between the planks of timber. In trials 2 in. deal planks are stated to have been dried in 10 hours; 4 in. ash felloes in 40 hours; 2 in. ash plough handles in 13

hours; in $\frac{1}{2}$ in. white deal cement-barrel staves in 30 hours; the loss in weight of the samples varying from 10 to 15 per cent. In the case of poplar and elm planks 1 in. thick, sawn six months after the trees had been felled, and placed in the kiln on the same morning they were cut, the time occupied in drying was about 70 hours.

A method of drying timber known as the patent vapour process dry kiln is used by the Grand Rapids Patent Vapour Process, U.S. This system can be worked either with live or waste steam, in the latter case the cost of working being correspondingly low. According to the proprietors of the process, 40,000 ft. of 1 in. oak which had been cut six months was thoroughly dried soft and bright, with no warping or checking whatever, in six days. The kiln used in this instance was 60 ft. in length by 17 ft. in width. The coal consumption was 5 cwts. a day for live steam.

Artificial Seasoning or Drying by Heat.

Desiccation or seasoning by heated air is carried out roughly by subjecting the timber in a kiln or chamber to a current of hot air, by which the sap is dried up. Seasoning can be effected in this manner in from a few hours to a few weeks, the time being dependent upon the size and characteristics of the wood to be operated upon. Application of the heat should be made very gradually when green timber is being dealt with, and considerable difficulty is experienced in preventing the wood from splitting. The temperature should not be too high, and the extremities of the timber should in some cases be clamped. The heat required varies according to the dimensions and kind of wood, the following being given as the usual maximum temperatures to be used for the woods mentioned:

	Degrees C	Degrees F.
Leaf-woods	41	105·8
Mahogany in thin boards . . .	149	300·2
Oak	44	111·2
Pine woods in deals and upwards . .	52	125·6
,, ,, in thin boards . . .	97	206·6

To ensure success in artificial seasoning the following conditions are essential:

(*a*) The boards to be dried in the kiln or chamber at the same time must be of a uniform thickness.

(*b*) The spaces or clearances left between the boards must always be equal.

(*c*) The kiln or chamber must be entirely filled with the wood to be dried, or, if this is impracticable, the partial charge should be boarded over on the top.

(*d*) The most suitable temperature for general use is 50°Cent. (about 122°Fahr.), any considerable excess of temperature above this—except for certain woods—producing inferior results.

Sir S. Bentham says, referring to timber seasoned by artificial heat, that " the due seasoning without cracking has appeared to depend on the ventilation happening to be constant, but very slow, joined to such a due regulation of the heat as that the interior of the timber should dry and keep pace in its contraction with the outer circles."

The diagram fig. 12 has been prepared by the Sturtevant Engineering Co., Ltd., to show the great advantage of heating the air for drying work. The ten curves correspond to the percentage of humidity form 10 to 100. The dew point for any given temperature is manifestly that at which the relative humidity is 100 per cent.—that is to say, when the air is saturated and incapable of taking up more moisture. A glance at the diagram will show that a cubic foot of air at

15·5°C. (60°F.) reaches its saturation point when it contains about 6 grains of moisture, whereas when it is heated to say 60°C. (140°F.) it is capable of taking up 56 grains before reaching saturation point. The two essentials for satisfactory drying are then, firstly, heat for accelerating the expulsion of the moisture from the material to be

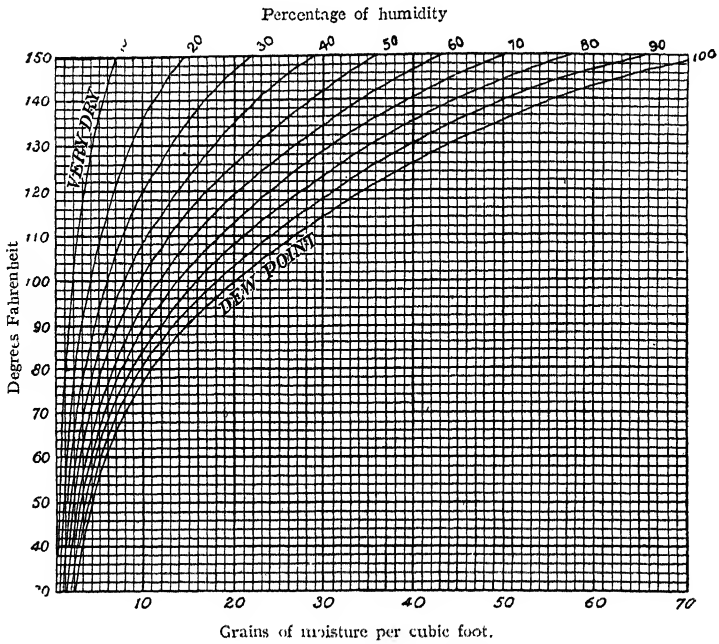


FIG. 12.—Diagram showing the advantage of heating air for drying wood.

dried and the evaporation of this moisture into the surrounding atmosphere; and, secondly, thorough air circulation to carry off the evaporated moisture.

The following table can be used to ascertain the degree of saturation or the relative humidity of air:

RELATIVE HUMIDITY—PER CENT.—(*U.S. Weather Bureau.*)

t (Dry Ther.)	Difference between the Dry and Wet Thermometers $(t-t_1)$.												t (Dry Ther.)
	0°·5	1°·0	1°·5	2°·0	2°·5	3°·0	3°·5	4°·0	4°·5	5°·0	5°·5	6°·0	
28	94	88	82	77	71	65	60	54	49	43	38	33	28
29	94	89	83	77	72	66	61	56	50	45	40	35	29
30	94	89	84	78	73	67	62	57	52	47	41	36	30
31	95	89	84	79	74	68	63	58	53	48	43	38	31
32	95	90	84	79	74	69	64	59	54	50	45	40	32
33	95	90	85	80	75	70	65	60	56	51	47	42	33
34	95	91	86	81	75	72	67	62	57	53	48	44	34
35	95	91	86	82	76	73	69	65	59	54	50	45	35
36	96	91	86	82	77	73	70	66	61	56	51	47	36
37	96	91	87	82	78	74	70	66	62	57	52	48	37
38	96	92	87	83	79	75	71	67	63	58	54	50	38
39	96	92	88	83	79	75	72	68	63	59	55	52	39
40	96	92	88	84	80	76	72	68	64	60	56	53	40

Table giving weights of aqueous vapour held in suspension by 100 lb. of pure dry air when saturated, at different temperatures, and under the ordinary atmospheric pressure of 29·9 in. of mercury.—(*Box and Lightfoot.*)

Temperature.	Weight of vapour.	Temperature.	Weight of vapour.
Fahr. degs.	lbs.	Fahr. degs.	lbs.
−20	0·0350	102	4·547
−10	0·0574	112	6·253
0	0·0918	122	8·584
10	0·1418	132	11·771
20	0·2265	142	16·170
32	0·379	152	22·465
42	0·561	162	31·713
52	0·819	172	46·338
62	1·179	182	71·300
72	1·680	192	122·643
89	2·361	202	280·230
92	3·289	212	Infinite

N.B.—The weight in lbs. of the vapour mixed with 100 lb. of pure air at any given temperature and pressure is given by the formula—

$$\frac{62{\cdot}3E}{29{\cdot}9-E} \times \frac{29{\cdot}9}{p}$$

Where E = elastic force of the vapour at the given temperature, in inches of mercury (to be taken from Tables).

p = absolute pressure in inches of mercury.
= 29·9 for ordinary atmospheric pressure.

Kilns for seasoning timber by the application of hot air may be broadly divided into two classes, viz., those

wherein a positive circulation of the air is effected by means of a fan or blower, and those wherein a natural circulation is employed.

DRYING OR SEASONING BY POSITIVE AIR CIRCULATION.

Desiccation has been in use for a considerable time. Many years ago the drying of wood in ovens was suggested by Wollaston and Fourcroy. Of the several more or less successful methods of drying by positive circulation devised in the first half of the last century mention may be made of the following:

De Mecquenem, in the year 1837, designed an apparatus comprising a closed chamber in which the wood to be dried or seasoned was placed. Currents of heated air are driven into this chamber through apertures at or near the floor level, and escape at the upper part thereof charged with the moisture extracted from the wood.

Charpentier, in the year 1839, patented in France an invention for drying wood in hermetically-closed chambers. The wood placed in the chamber is subjected to a current of air heated by contact with metal plates arranged to form the covering of the flue of a coke furnace. As in the previous arrangement, the hot air enters the chamber at the floor level, and escapes at the top through suitable apertures, whence it is conveyed into the furnace chimney.

Davison and Symington, in 1844, introduced a patented apparatus and process for drying timber by means of propelled currents of heated air, the heat being regulated according to the nature of the wood in the stove. The apparatus consisted essentially of a furnace and a series of pipes within a core of brickwork. On each side of the furnace, on a level with the fire bars, is a horizontal tube; communicating and springing from these tubes

are a series of eighteen tubes placed vertically and parallel to each other over the furnace. The outer end of one of the horizontal tubes communicates with a fan or blower by which a constant current of atmospheric air is driven through the tubes, wherein it is raised to a considerable temperature and is discharged at the further extremity of the other horizontal pipe, and thence conveyed to the stove or chamber. The wood is placed in a closed chamber, gallery, vault or flue of suitable form or magnitude, preferably constructed of fire-brick, with double doors or shutters for introducing or removing the wood. These chambers may be constructed in sets in parallel lines in the floors or upright walls of a building, with narrow openings through which the heated air may issue in thin streams and spread itself over the surface of the wood. Should the inlets be near the floor the wood should be placed in an upright position; if, however, it be admitted horizontally, standards and skeleton shelves will be required upon which to lay the wood, the great desideratum being to bring the heated air as quickly as possible into contact with the wood and to permit it to pass away as rapidly as possible after it has done its work.

According to the inventors, the total superficial area of the open space in the floor, or in the upright walls, for the stream of hot air to pass to the wood should not exceed that of the principal outlet pipes at the end of the furnace. In this way a free and uniform current of hot air is caused to flow through the chamber, or chambers, containing the wood. The best temperature to be given to the air, and velocity of the current, will depend in each case upon the size, density and maturity of the wood to be treated. Experiments made by the inventors are stated to have showed that wood generally may be

subjected with advantage to currents of air at a temperature of 204°Cent. (399·2°F.) and a velocity of 100 ft. per second. For green wood, however, it is considered by them preferable to commence at a temperature of from 66° to 93°Cent. (150·8° to 199·4°F.) and raise it gradually as desiccation proceeds. To effect this a cold air drain from the fan, provided with a damper, is suggested, so that the temperature of the hot current of air may be regulated at will.

It is held that wood may safely remain under treatment until there is no further escape of moisture, which should be until the loss of weight is from one-quarter to one-twelfth of the whole weight of the wood.

Several patents for stoves for drying wood were obtained by Bethel between 1848 and 1853. That taken out in the first of the above years comprises a rectangular chamber consisting of three walls vaulted over, constructed of brickwork with a core of slag. The wood is introduced at one extremity of this chamber on trucks running on longitudinal iron rails, a double door being provided for closing the aperture when the kiln is charged. At the opposite end to this door is a furnace for burning coal, coke, wood, or tar. The hot air, when drying only is required, or smoke when it is desired to smoke it and so impregnate it with gaseous antiseptic matters, enters through a flue running along the floor and branching at the end, and is allowed to escape, or is sucked out by a suitable exhaust fan at the top of the kiln.

Bethel considered the best temperature to be one of 43°Cent. (109·4°F.), and the time required from eight to twelve hours.

A stove or kiln for drying wood for flooring was designed about 1870 by S. T. Holmes. The air is heated in this dryer—which is said to have been very successful—

by means of a warming apparatus invented by Price and Manby.

An example of a modern kiln working on the above system is shown in fig. 13. This timber-drying kiln has three compartments, each under separate control, and has been designed and patented by the Sturtevant Engineering Co., Ltd. In this timber-dryer both the temperature and circulation of the air can be regulated, and also the humidity, by which means it is claimed that hardwood and large balks of timber can be treated as effectively as small pieces of softwood. Hardwood, owing to the closeness of the grain, does not part with its moisture so readily as softwood, consequently when subjected to the action of hot dry air only, the outer skin becomes dry and is liable to warp and split before the moisture evaporates from the heart of the timber. The subsequent gradual evaporation of this internal moisture causes contraction and further warping and splitting.

In operating the kiln under consideration large balks of hard wood piled in one of the compartments can first of all be subjected to the gentle action of moist cool air, and the temperature of the air can be raised by degrees as desired, the timber being thus gradually warmed up. In this way the moisture can be slowly evaporated from the heart of the timber without the outer skin becoming dried. The humidity of the air is slowly decreased, whilst the temperature is slowly raised, and, when the drying process is nearly completed, warm dry air is admitted to finish the drying. At the same time, it is possible to have in the other compartments conditions exactly suitable for drying smaller pieces of hardwood or of soft timber.

The system comprises three main distributing ducts, the first of which supplies the warm dry air, the second

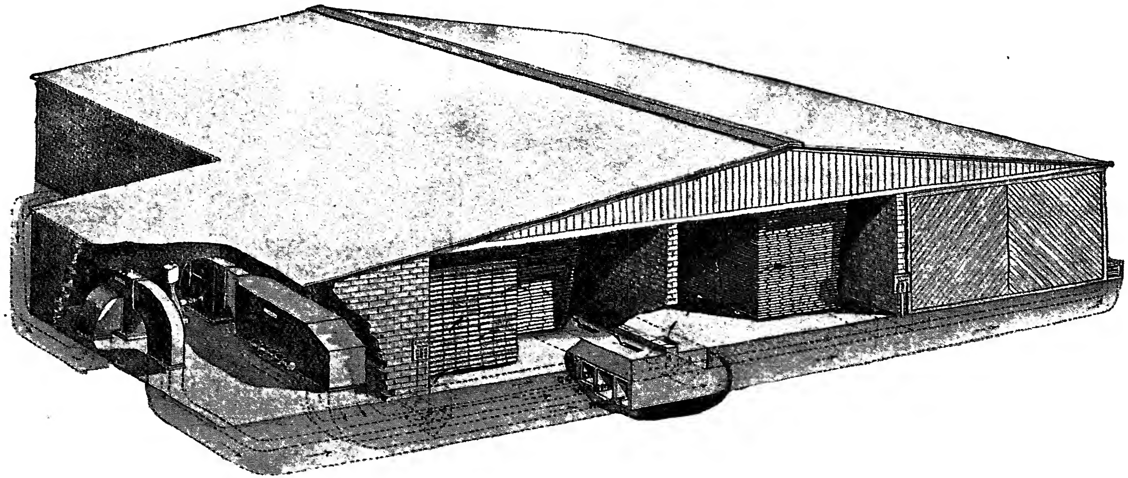


FIG. 13.—Sturtevant Timber-drying Kiln with positive circulation.

cold dry air, and the third moist air. Suitable branch supply ducts connect the compartments with these three main ducts, and discharge ducts are also provided. The admission of air can be regulated by dampers, worked from the control board, shown in fig. 14, which is placed outside the kiln. These dampers can be adjusted to any position, the conditions prevailing in each of the compartments of the kiln as regards humidity, temperature, and air circulation being indicated on the control board.

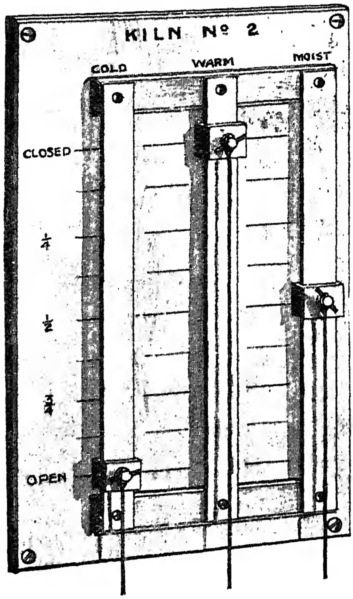


FIG. 14.—Control board for use with the Sturtevant Timber-drying Kiln.

The circulation of warm air through the compartments is positive and is effected by a fan or blower in connection with a steam heater for warming the air, and a return water apparatus for delivering the hot water discharged from the heater direct to the boiler. The warm air on entering the drying compartments gives up the greater part of its heat in evaporating moisture, and after passing through the wood leaves the drying compartments, carrying with it the vapour, thus not only supplying the heat which evaporates the moisture, but also absorbing that moisture and carrying it away to the exterior.

The centrifugal fan used is a patent Sturtevant steel-plate fan of the M.V. type, the main feature of which is

the wheel or runner. This latter is built up with a large number of concave blades which are curved forward so that the concave side faces in the direction of rotation,

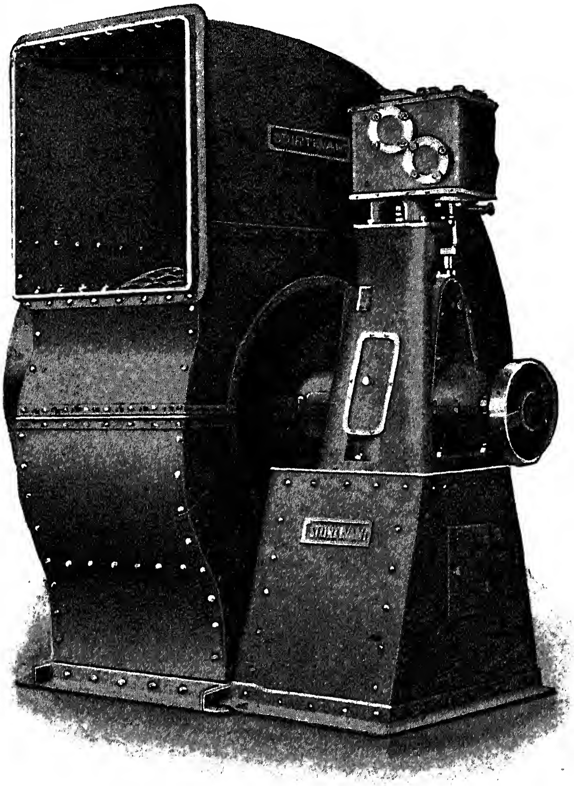


FIG. 15.—Enlarged view of Centrifugal Fan used with Sturtevant Timber-drying Kiln.

and, what is of more importance, has the blades so constructed that they are not straight from end to end, but consist of a series of pockets approximately spoon-shaped, as will be seen in the illustration, fig. 15, which shows the

fan drawn to an enlarged scale. The makers claim that with this type of wheel a much larger volume of air is passed through the fan when running at the same speed as the ordinary centrifugal fan-wheel. This excess in the amount of air handled is said to be due to the fact that the numerous spoon-like pockets take hold of a larger quantity of air than a flat blade is capable of doing.

The following explanation of the principle upon which the system operates is given by the inventors: A substance becomes dry by evaporation of its inherent moisture into the surrounding space. If this space be confined, it soon becomes saturated and the process stops. Hence constant change is necessary in order that the moisture given off may be continually carried away. In practice, therefore, air movement is, in their opinion, absolutely essential to the process of drying. The introduction of heat serves to decrease the time of drying by increasing both the rate of evaporation and the absorbing power of the surrounding space. Whether this space be a vacuum or be filled with air it will, under either condition, take up a stated weight of vapour. If the temperature of the space be increased, opportunity will thereby be afforded for the vaporization of more water, but if it be decreased the capacity for moisture will be reduced and visible water will be deposited. The temperature at which this takes place is known as the dew point.[1] An everyday application of the above principles in nature is found in the rapid drying of the roads and buildings on a windy, sunny day, the sun providing the necessary heat, and the wind serving to remove the moisture drawn up by the sun's rays.

[1] In this country the dew point is rarely more than 30° below the temperature of the air.

The atmosphere is universally recognized as the best medium for the absorption and removal of moisture. Its capacity for absorption, or more properly speaking the amount of vapour a given space will contain, increases rapidly with the temperature. It is principally for this reason that heat is such a valuable factor in the drying process. The degree of saturation or of humidity is usually expressed relatively in per cent. of the total amount of moisture which the air would be capable of taking up at a given temperature. The air is saturated when it is incapable of taking up and holding invisible any additional amount of vapour. In other words, the actual temperature of the mixture and the dew point then coincide, and the least cooling would cause deposition of moisture.

Figs. 16, 17 and 18 show in plan, sectional elevation, and cross section a timber-drying chamber, also working, on the positive circulation system, designed by Mr. G. F. Wells. The main feature in this dryer is the arrangement for heating the air and for circulating same through the apparatus, which consists, as shown more clearly in the enlarged view fig. 19, of a combined accelerated hot-water boiler with steam superheater, hot-water battery, and a blower fan, marked respectively D, E, and F on the plan. The boiler is specially designed so that if necessary it can be worked entirely on wood refuse. The lower part of the boiler heats the water and rapidly circulates it through the air heater or battery, and the fan forces the hot air through the inlet or delivery-duct into the drying chamber.

Directly above the hot-water heater is a small steam boiler and superheater, worked by the heat from the same fire. The superheated steam from this combined apparatus is delivered into the air and steam mixing

chamber G. This chamber is placed for convenience between the heating battery and the fan.

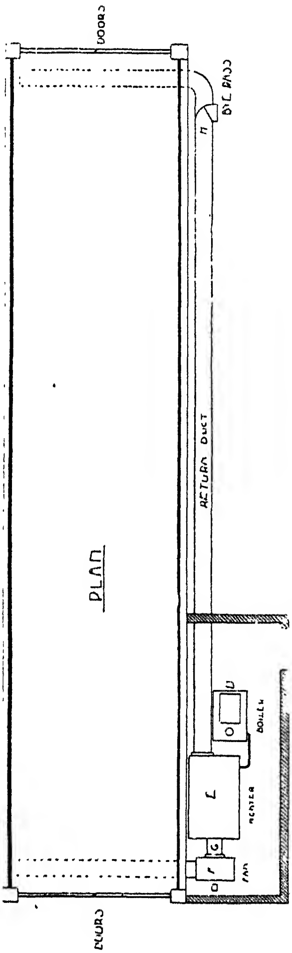


FIG. 16.—Wells' Timber-drying apparatus with positive circulation. Plan.

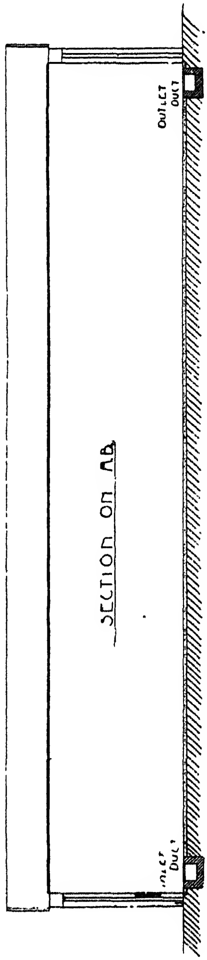


FIG. 17.—Wells' Timber-drying apparatus with positive circulation. Sectional elevation.

The operation of the apparatus is as follows: The timber-drying chamber is first stacked with the sawn timber, taking care to fill up the spaces as far as possible;

or, if the continuous or progressive system is adopted, it is piled or stacked on trucks. The doors of the chamber

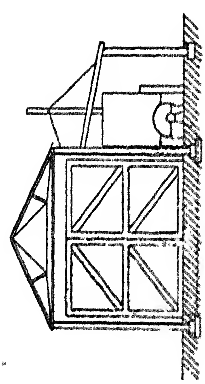


FIG. 18.—Wells' Timber-drying apparatus with positive circulation. Cross-section.

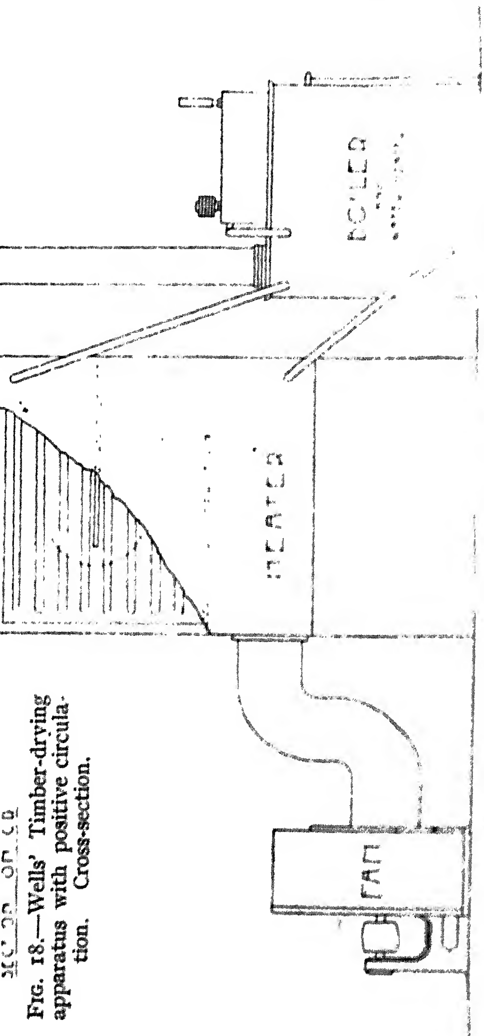


FIG. 19.—Wells' Timber-drying apparatus. Enlarged view, showing heater, etc.

having been closed, the combined mixture of hot air and superheated steam is driven into the chamber through

the inlet duct by the fan, the low temperature of the wood causing the steam to condense on its surface; so that it is entirely covered with a thin film of moisture, which is claimed by the inventor to prevent cracking, and to open the pores of the wood.

After this sweating process has been allowed to proceed for a short time, the supply of superheated steam to the hot air in the mixing chamber is discontinued by simply closing a damper in the furnace beneath the steam boiler. The drying-process is then continued by permitting the hot and moist air to continually circulate through the drying-chamber and back through the return air duct to the heater and to the fan, which again passes it into the drying-chamber. This operation is continued until the air so circulated has become fully saturated with moisture, when the by-pass H in the return air duct is put into operation, and part of the saturated air is allowed to escape into the atmosphere through the by-pass, the rest passing on to the heater and fan. By this time the drying process will be nearly completed, and only requires to be continued for a short time longer, when the doors can be opened and the dry timber removed.

Drying or Seasoning by Natural Air Circulation.

A patent timber dryer, designed by Erith's Engineering Co., Ltd., arranged to operate with a natural air circulation, is shown in figs. 20 to 24. The first is a perspective view taken at the discharging end of a progressive dryer for pine boards and deals with two tunnels. Fig. 21 is a plan view, and figs. 22 and 23 are longitudinal and cross sections showing details of construction.

This automatic dryer consists of one or a plurality of tunnels each having independent control both as regards temperature and humidity. Thus any convenient number

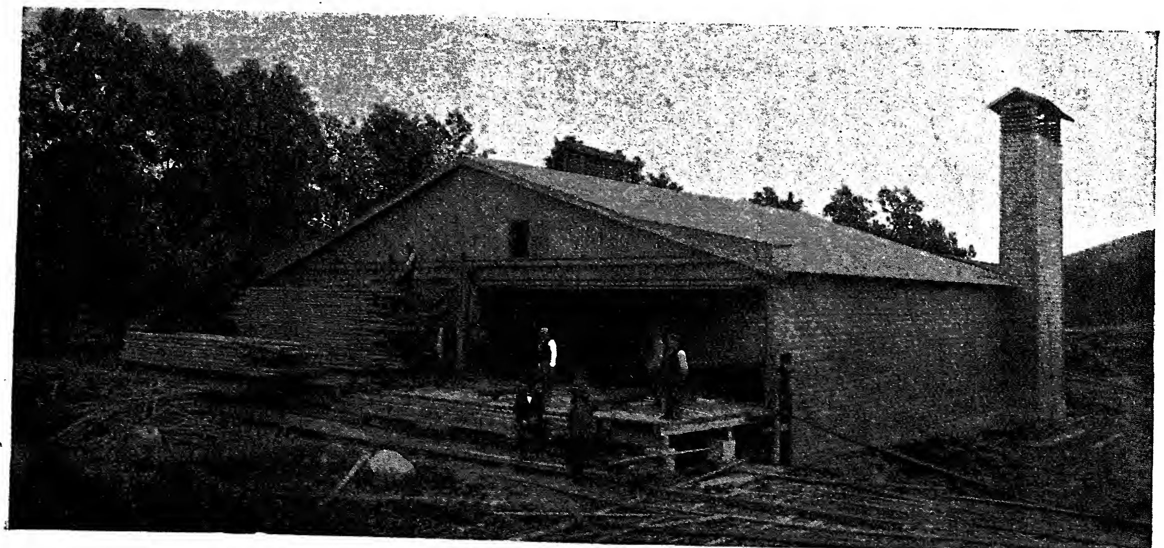


FIG. 20.—Erith's Progressive Dryer for hardwoods, with two tunnels. Perspective view at discharging end.

may be built in series, each tunnel being a self-contained unit, and the drying is effected by a rotary circulation of moist air without any mechanism. Each tunnel is provided with a platform at its charging end and at its discharging end, and with suitable doors, as shown more clearly in the vertical longitudinal section, fig. 22. The timber to be dried is stacked on trucks, as shown in fig. 24, and these trucks are arranged to travel through the tunnel on rails.

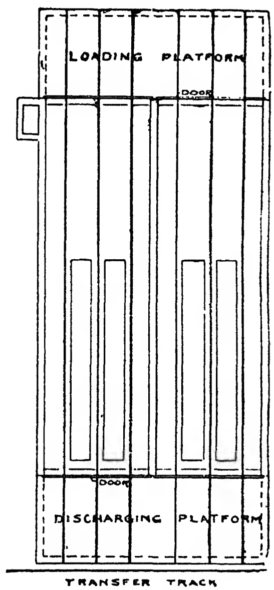


FIG. 21.—Erith's Progressive Dryer for hardwoods, with two tunnels. Plan.

The building in some installations is a fireproof construction of brick and iron, the doors being Erith's improved wood or canvas roller pattern, which can be as rapidly pulled up as a blind, but which fit tight when lowered.

The heating device comprises a series of steam radiator coils, using either live or exhaust steam, mounted in the air space situated beneath the tunnel as shown in figs. 22 and 23, and extending from the discharging end to somewhat more than half its length.

The principle upon which this dryer works is an air circulation entirely produced by convection currents. The hot air coming from the steam coils rises and passes in an upward direction through the timber, and afterwards through the tunnel, and downwards to the air space, along which it passes back to the steam radiator-

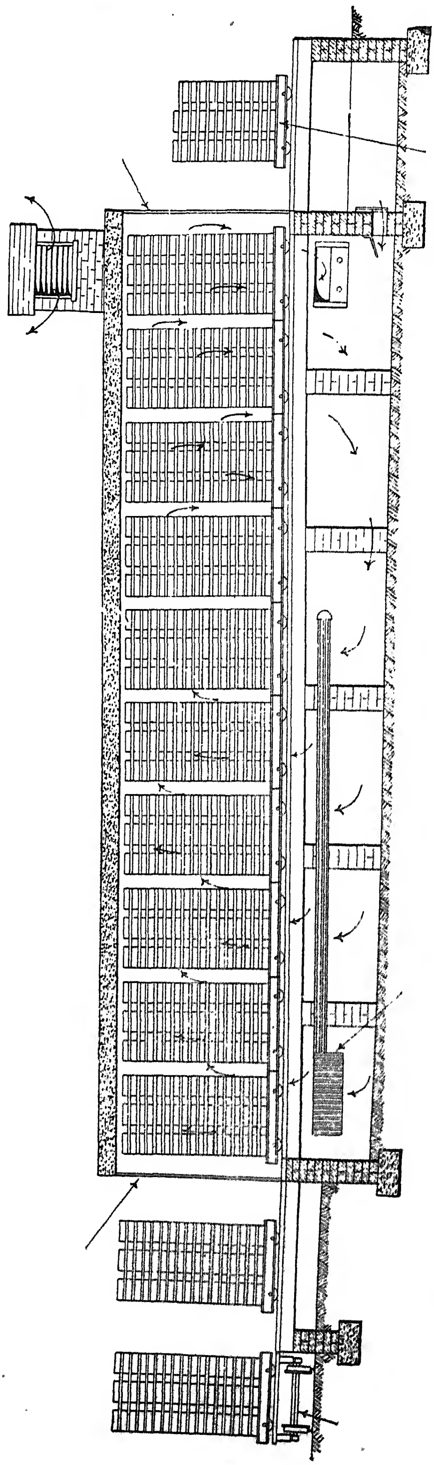


FIG. 22.—Erith's Progressive Dryer for hardwoods. Longitudinal section, showing details of construction.

coils, the course being indicated by the arrows in fig. 23. It will be understood that the tunnel is not floored, the rails being supported upon cross-joists above the air space.

As the air flows along the tunnel it comes successively in contact with wood in a wetter and wetter condition, and is slowly cooled until on its arrival at the charging end it falls down into the air space and returns as above mentioned to the heater to be again warmed and circulate as before, thus the final drying is effected by the hottest air. This continuous circulation might result in the air becoming too much charged with moisture, and to obviate this an outlet stack is provided, as shown in

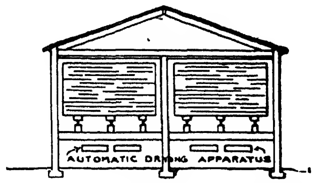


FIG. 23.—Erith's progressive dryer for hardwoods. Cross-section, showing details of construction.

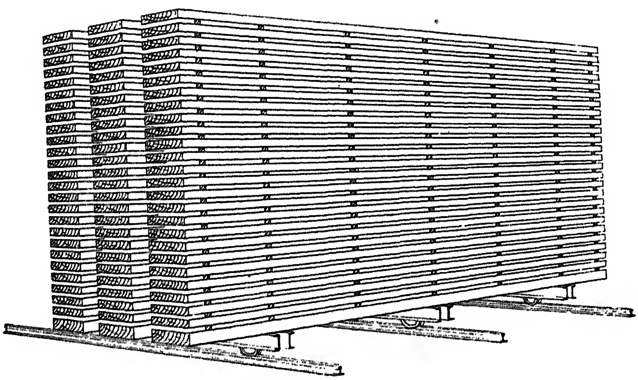


FIG. 24.—Erith's Progressive Dryer for hardwoods. Perspective view, showing method of stacking timber to be dried on trucks.

the drawings at the charging end, and also an inlet for the admission of fresh air from the exterior, as shown in fig. 23, both outlet and inlet being controlled by suitable dampers.

At the discharging end of the tunnel is a transfer arrangement (*see* fig. 22) which admits of the loaded trucks of dried wood being run on to a transfer car and moved to any desired point for unloading.

The trucks consist of a couple of joists with two grooved wheels mounted on roller bearings, and generally the wood is stacked on three of these trucks, the weight of the wood being sufficient to maintain them in position, and a series of three rails being provided in the tunnel. When long narrow boards are to be treated, they are piled as shown in fig. 24, each tier of boards being separated by piling sticks 1 in. square, this open piling ensuring uniform drying, as the moist warm air has free access to every board. If short lengths have to be dealt with, full-length deals are placed across the trucks to support the tier of boards. Heavy material such as mahogany or oak balks can also be dealt with, and the inventors claim that balks 11 in. square have been successfully treated.

The temperature is controlled by a single steam valve placed outside the tunnel in an easily accessible position. Any degree of humidity from a slight mist to a dense fog of warm air can be obtained, and moist air is used throughout the process; dry air is only admitted in such quantity as may be necessary to prevent complete saturation.

Drying or Seasoning by Oxygen.

A process for artificially seasoning wood devised by Mr. C. René, a pianoforte manufacturer of Stettin, Germany, consists of an apparatus comprising a closed cylinder or kiln in which the wood to be treated is placed on iron gratings. Adjacent to the above-mentioned kiln, and connected therewith by a pipe governed by a stop-cock or valve, is located a retort for the generation of oxygen,

which latter is admitted into the kiln. Suitable provision is made in the kiln to ozonize the oxygen by means of a current of electricity, the kiln being then gently fired and maintained in a heated condition for from 48 to 50 hours, after which the process of seasoning is said to be complete.

Drying or Seasoning by Smoke.

Seasoning by smoke-drying was practised in very early times, and the hardness and soundness of timber found in ancient houses may be attributed to the fact of their being exceedingly smoky.

A patent was obtained in France about 1870 for a process of smoke-drying wood, claimed to be more expeditious and certain than the use of hot air only, and which process is stated to have been in successful operation near Cherbourg. The process, which was invented by Guibert, consists in charging the stove or chamber for drying the wood with smoke produced by distilling such combustible materials as sawdust, waste tan, smiths' coal, etc. A ventilator is so arranged as to produce a rotatory motion of the smoke, in the kiln or chamber, round the wood to be seasoned, thereby ensuring a uniform temperature in every part thereof. It is mentioned that as the process of distillation is invariably attended by a considerable discharge of steam, the drying or seasoning is effected in a moist atmosphere and cracking or splitting of the wood is avoided.

Drying or Seasoning by Scorching or Charring.

Seasoning by scorching and charring is a method at one time used for preserving ships. The process is said to

protect wood from the attacks of insects, etc., and is a good one for preventing external infection, but must be performed slowly and only in the case of timber already well seasoned, as otherwise it tends to hasten the decay of wet timber. Charring has, however, practically no effect as regards the prevention of internal corruption. For the preservation of fence-posts the plan is an excellent one, the charring being extended some distance above their contact with the ground. The charred portions may with advantage be painted with three or four coats of pitch. Charring has been used with good results in Belgium for the preservation of sleepers.

Drying or Seasoning by Electricity.

A method of effecting the rapid seasoning of timber by means of electricity has been proposed by Nodon-Bretonneau (G. Mareschall, *La Nature*, October 7, 1899, p. 296), to whom it has occurred that the sap could be more readily displaced by the aid of a current of electricity. The apparatus consists of a wooden tank having a false bottom constructed of open woodwork, and capable of being raised by means of hydraulic rams. The bottom of the tank is covered with sheet lead, and is electrically connected with the positive pole of a dynamo, and a steam heating coil is provided between this lead bottom and the false bottom. The timber to be seasoned is stacked upon the false bottom, and above the timber are mounted shallow boxes having bottoms formed of felt or cloth, and each of which forms a sort of porous vessel which is filled with water. By means of a framework or mounting of lead, these porous water vessels are electrically connected with a negative current of electricity. The tank is filled with a solution such as a neutral boro-resinate of soda, or other suitable solution, with which it is intended

to replace the sap in the timber, and the contents are then gently heated by means of the coil of steam-pipes beneath the false bottom.

The current of electricity passes through the entire depth of the timber stacked on the false bottom between the lead bottom and the porous-bottomed water vessels or boxes, and by its action it is stated to induce a species of electrical endosmosis, the solution in the tank surrounding the timber replacing the sap in the latter, and the expelled sap escaping and floating on the surface of the bath.

The operation is said to be complete in a few hours, when the timber is removed from the tank, and after being allowed to drain in the open air, the drying process is completed in a kiln having suitable means for regulating the temperature.

Effect of Time on the Strength of Wood.

The influence of time on the strength of wood formed the subject of a comprehensive series of experiments made in 1893, and which were again repeated in 1895, in the testing-shops of the Chalmers Institute in Göteborg, Sweden, on the transverse strength of pine, spruce, oak, and birch. In the year 1901 another series of experiments were made by Mr. Theodor Wijkander in the same laboratory (Teknisk Tidskrift, Stockholm, 1904) with bars of the same woods, which had remained stored during this interval of time in roomy and dry lofts of the shop. The general section of the bars was 10 centimetres (3·938 in.) square. These bars were completely air-dried at the time of the first tests. For the later tests the bars were dried at a temperature of 38°Cent. (100°Fahr.) for from 10 to 12 days, whilst for the first tests they were only dried

for 8 days, so that they were about 2 per cent drier in the latter case.

The later tests were carried out in exactly the same way as the first ones, and the mean results of the three tests show that between 1893 and 1895 the moduli of breaking and of elasticity had increased, whilst the deflection had diminished, the wood having become stiffer. From this it was concluded, at the time, that the wood had undergone some internal change during the interval between these two tests. The results of the tests carried out in 1901 showed that the moduli of breaking under compression, bending, and shearing had increased, as also that of elasticity in bending, and the deflection which had been found to have diminished during the period from 1893 to 1895 was found to be on the increase in 1901. This increase, however, showed no regular correspondence with the lapse of time.

Effect of Moisture on the Strength of Wood.

The strength and elasticity of wood depend to an appreciable degree upon the amount of water which it contains, and it is therefore desirable to know to what extent the strength of wood is impaired by the absorption of water hygroscopically. Investigations with this object in view were made by Mr. Julius Marchet in 1895–6 (*Mittheilungen des K. K. technologischen Gewerbe-Museums in Wien*, 1895, p. 204, and ibid. 1896, p. 82) with three varieties of hornbeam.

The wood was tested by compression in the form of cubes, having sides of 1·4 inch with an area under compression of about 2 square inches. The results given are the mean of five tests. The weight needed to crush the cubes of dry wood varied from 19,621 lb. to 25,794 lb. The tests were made upon an Emery testing machine,

the figures being the point reached at which the indicator dropped back, showing that the breaking down crushing strain had been reached.

The cubes treated with water were allowed to float until thoroughly saturated, which varied in from six to seventeen days. The dry cubes contained from 7·7 per cent. to 9·8 per cent. of water, showing that the wood was well seasoned. The weight of water absorbed varied largely in different samples of wood, and ranged from 45 to 79 per cent of the weight of the dry wood on the seventeenth day. The weights required to crush the saturated cubes varied from 9,038 lb. to 11,023 lb., the loss of strength ranging from 55·9 to 61 per cent.

The second series of tests were made with further specimens of the same woods from a different locality. Four test-bars were made of each of the two varieties of hornbeam employed, the dimensions being uniformly 26·1 inches in length and 1·3 inch square.

Some of these bars were tested in their dry state to ascertain relative strength, and two were soaked in water. The dry bars contained from 22·5 to 31·4 per cent. of water, and those steeped in. water from 33 to 48 per cent. of water. The first were therefore far from being properly air-dried, whilst the latter were not fully saturated, having, owing to lack of time, been removed from the water after only nine days. In every case the pieces tested had a clear bearing of 21·26 inches, and the weight was gradually applied at the centre.

From the results of the tests the following deductions were arrived at: The two varieties of hornbeam tested showed when wet a reduction of the crushing strength, as compared with that when dry, of from 55 to 60 per cent.; the bending strength, however, showing only a decrease of 10 per cent.

The deflection of the wood is increased by the absorption of water. The ultimate breaking stress coincides approximately with the extreme range of elasticity when the wood is saturated with water. The stress of bending in the case of saturated wood is about 60 per cent. lower than in the case of air-dried wood tested dry.

The tests cited above demonstrate the loss of transverse strength and crushing strength in the case of a certain variety of hardwood, owing to the absorption of water.

The effect of moisture on the strength of woods more frequently employed in construction has formed the subject of extensive investigations by the United States Forest Service. The following is a brief abstract of some of the results obtained during these tests published in the *Engineering and Mining Journal* of New York (November 10, 1906). It was found that the relation of moisture to strength follows a definite law, that the strength of all kinds of wood increases rapidly with proper drying, the amount of increase depending on the species and the degree of dryness. Thus the strength of a piece of unseasoned red spruce may be increased over 400 per cent. by a thorough drying at the temperature of boiling water. The strength of the dry wood, however, decreases again as it reabsorbs moisture. Wood air-dried and protected from the weather containing 12 per cent. of moisture is according to species 1·7 to 2·4 times stronger than when green. The stiffness of wood is also increased by drying.

The above conclusions have been arrived at from tests conducted with pieces of small cross-section not exceeding 4×4 inches (10·2×10·2 centimetres). In the case of timber of large sectional area, however, years of drying would be required before the moisture becomes

reduced to the point at which the strength commences to increase. Under normal conditions it was found that wood fibre will absorb a definite amount of moisture; any additional amount of water then only fills up the pores, and has no practical effect on the strength.

The following percentages estimated on the dry weight of the wood were found to be the fibre-saturation points for the woods named: Long-leaf pine 25; red spruce 31; chestnut 25; red gum 25; red fir 23; white ash 20·5; Norway pine 30. Wood which had been dried and re-soaked was found to be slightly weaker than the same wood when green.

CHAPTER IV

The Preservative Treatment of Wood.

Conditions Essential to ensure Success—The Absorption of Preservatives by Wood—The Slit Hypothesis—Weiss' Theory—The Structure of the Pit Membranes in the Tracheids of Conifers and their Relation to the Penetration of Gases, Liquids, and Finely Divided Solids into Green and Seasoned Woods—Detailed Structure of the Pit Membranes—Laboratory Analysis after Treatment *v.* Actual Record during Treatment.

CONDITIONS ESSENTIAL TO ENSURE SUCCESS.

THE lower forms of animal and vegetable life, that is to say bacteria, fungi or spores, assisted by heat, air, and moisture, enter the wood cells and destroy the wood tissue, and as these destructive elements are always present and ready to attack organic matter, it becomes necessary both to destroy them and to render the wood impervious to them by the injection of some antiseptic or poison in liquid form.

Processes for the preservation of timber from decay, and from destruction through the boring of insects, may be classified under three headings: Drying artificially and hermetical protection from contact with the atmosphere by coating the surface with paint; the elimination of the sap of the wood by dilution or vaporization; the impregnation of the wood with some antiseptic chemical substance which will form an insoluble compound with the organic matters in the sap.

The first and second of the above methods are only

valuable where the timber is comparatively thin, is so placed as to be readily get-at-able, and is not in contact with the ground. The third is the most important, and it is proposed to deal chiefly with processes coming under this head.

It is absolutely necessary in order that an antiseptic agent should produce useful results in the preservation of wood that it be in a proper liquid state at the instant at which injection into the wood takes place, and to ensure success commercially, that the operation can be carried out at a reasonable cost.

It is also essential that the operator should have a thorough insight into the practical working of the process employed, and a knowledge of the nature of the preservative used.

The wood to be treated should, moreover, be in a proper condition, that is to say, properly seasoned, or at the very least half-seasoned. In the best practice in Europe the wood is not treated until it has been seasoned from six to twelve months. In the United States, however, wood is frequently treated four to six months after cutting, but generally with inferior results.

THE ABSORPTION OF PRESERVATIVES BY WOOD.

The whole problem involved in timber preservation is the replacement of the sap of the wood by some suitable preservative agent, and before proceeding to discuss the various antiseptics and systems of application employed, a few observations upon the fundamental factors controlling the penetration of preservatives into wood may materially assist in clearing away some of the difficulties that occasionally confront those interested in the timber-preserving industry, through results being obtained

in practical working which cannot be satisfactorily explained.

With this object in view the following abstracts are given of two papers on "The Preservative Treatment of Wood," by Mr. Irving W. Bailey, Assistant Professor of Wood Technology, Harvard School of Forestry, Bussey Institution, Jamaica Plain, Massachusetts, U.S.A., which papers appeared as contributions from the laboratory of wood technology of the above school, in a recent number (Vol. XI. No. 1, March, 1913) of the *Forestry Quarterly*, a professional journal published in Ithaca, New York. The writer has to thank Professor Bailey for his courtesy in lending him the original negatives, so as to enable him to take prints from which the photomicrographs figs. 25 and 27 have been prepared.

The Slit Hypothesis.

The first of these articles treats of the validity of certain theories concerning the penetration of gases and preservatives into seasoned wood. The author analyses Tiemann's hypothesis and summarizes it by the following extracts from a paper by H. D. Tiemann on *The Physical Structure of Wood in relation to its Penetrability by Preservative Fluids* (Bulletin 120, American Railway Engineering and Maintenance Way Association: "In fresh green wood of all species the cells of all kinds (except the resin ducts and the vessels) are completely closed by the primary wall, and the gases cannot be forced through this enclosing membrane even at extreme pressures. Water may percolate through this membrane gradually, as through a filter, but this action must be comparatively slow even under high pressure . . . Whenever wood seasons (beyond its fibre saturation point), whether naturally or by artificial means, narrow microscopical

slits occur in the walls of the fibres and tracheids which render them penetrable to gases and liquids. These slits do not reunite when the wood is re-soaked, although they may close up somewhat. The greater the degree of dryness the more penetrable the wood becomes . . . Steaming opens up these slits in the cell walls, but they are not as numerous nor as wide as in air-dried material."

"This hypothesis," says Mr. Bailey, "strengthens the position of those impregnation experts who claim that timber must be thoroughly air-dried to secure a rapid, thorough penetration. Furthermore it apparently explains the value of preliminary steaming under pressure in kiln-drying green lumber. It indicates the reason why wood dried and then re-soaked is weaker than the original green material, why the failure of re-soaked beams resembles that of dry beams, etc., etc.

"*Distribution of 'slits' in air-dry wood.*—As a special test of this point Mr. Bailey has examined thin sections cut from one hundred specimens of thoroughly air-dried wood. The material included all the important timber-producing conifers or 'softwoods' of the United States. Spiral cracks in the cell walls occurred (as a result of drying or seasoning) in 10 per cent. of the material examined. In the remaining 90 per cent. the walls were entire, unruptured by the heavy stresses produced by contraction of the cells in drying. The examination of a large number of thoroughly air-dried dicotyledons or 'hardwoods' showed as in the case of the 'softwoods' that cracking of the cell walls in drying is of comparatively limited occurrence. Furthermore, numerous experiments showed that air may be passed as easily through the unruptured dry material as through the material whose cell walls had been 'slit' in drying.

"*Distribution of 'slits' in the annual ring.*—In all the

material of coniferous woods examined by the same authority the drying cracks or 'slits' were invariably confined to the heavy thick-walled cells of the so-called 'summer' or 'autumn wood' (Sr.), which are formed during the last part of the year's growth as shown in 1 and 4, fig. 25. The larger thin-walled cells of the so-called 'spring wood' (Sp.) were unruptured and therefore, according to Tiemann's theory, impervious to gases and heavy oils. Yet, as Tiemann has figured clearly (H. D. Tiemann, *The Physical Structure of Wood in relation to its Penetrability by Preservative Fluids*,' p. 8), air passes very rapidly through the thin-walled cells of dry 'spring wood.'

"*Distributing of 'slits' in the layers of the cell wall.*—The wall of a wood cell is not chemically and structurally homogeneous throughout, but is differentiated in most cases into three more or less clearly defined layers or coats. The outer membrane or layer, which is supposed to entirely enclose the rest of the cell, is called the primary wall, and is considerably thinner than the succeeding layer within, which is heavily lignified and very variable in thickness (4, fig. 25). The latter layer is called the secondary wall and is separated from the lumen or cavity of the cell by a third, usually extremely thin, layer or tertiary wall (7, fig. 25). The secondary wall is comparatively thin in the large 'spring-wood' cells, but becomes much thicker in the cells formed at the end of the year's growth (4, fig. 25). As has been stated, cracks or 'slits' due to drying are confined to the heavy walled cells of the 'summer wood' (*see* Sr. 1 and 4, fig. 25). If very thin, carefully cut and stained sections are examined under high powers of magnification, it becomes evident at once that the so-called 'slits' or rents in the cell walls are confined entirely to the secondary and

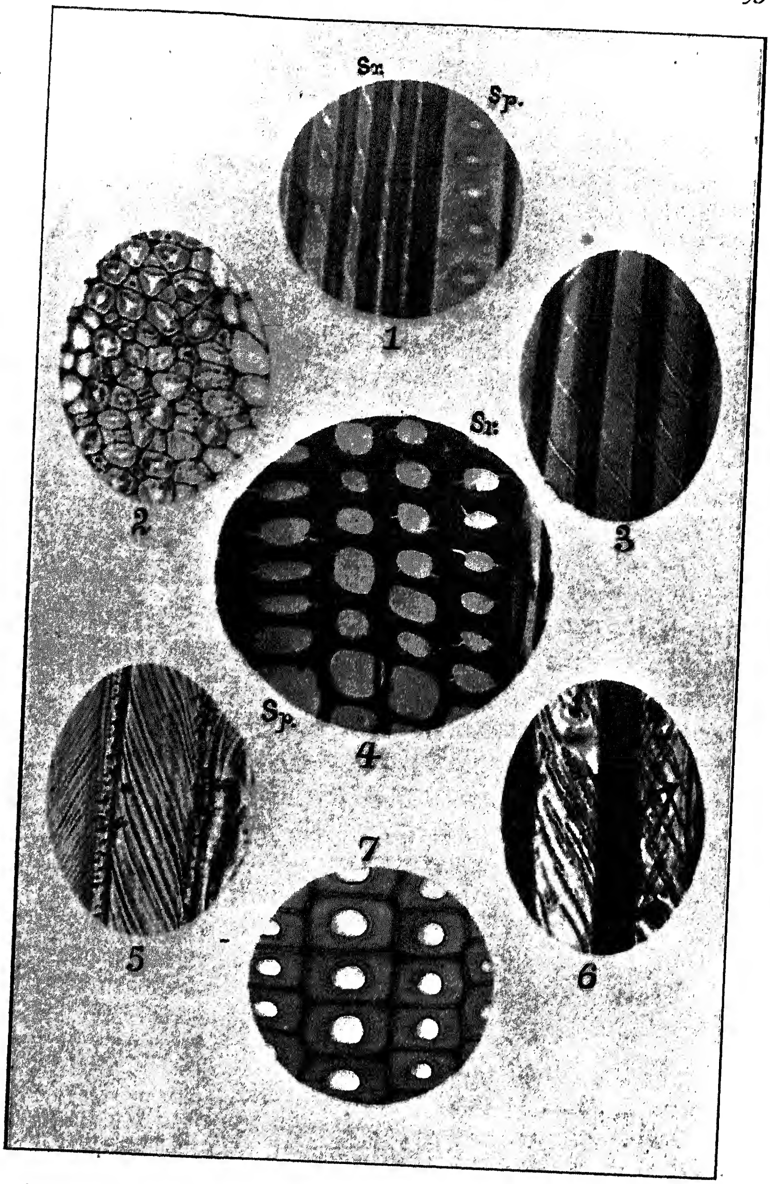


FIG. 25.—Photomicrographs illustrating the validity of the slit hypothesis.

tertiary layers (*see* 4, fig. 25). The primary walls remain unruptured, preventing effectively the penetration of gases and heavy oils from one cell to another by means of the cracks in the secondary walls. In 4, Fig. 25, a cross section of pine wood, it may be noted that in order for air to pass from one cell cavity to another it must pass through two layers of unruptured primary wall, which together possess considerable thickness, equal in many places to the thickness of a single layer of secondary wall. A similar condition is illustrated in 2, fig. 25, as cross section of the fibres of a 'hardwood' or broad-leaf tree. From this it is clear that drying cracks or 'slits' even when present cannot account for the rapid penetration of gases and preserving fluids.

"*Penetration of air through green wood and re-soaked dry wood.*—The observations of Professor Bailey confirm the theory of Tiemann that the spiral cracks when once formed do not close when seasoned material is re-soaked. In view of this fact it is significant that in many cases dry wood when thoroughly re-soaked is, under moderate pressure, as impervious to air as unseasoned material. Furthermore, although long pieces of green sap-wood are impervious to air, even under heavy pressure, short pieces of the same wood, more than one fibre length long, may be penetrated easily and rapidly and by slight pressure."

WEISS' THEORY.

"*Weiss' modification of Tiemann's hypothesis.*—In a paper read before the American Wood Preservers' Association, Weiss[1] explains the greater penetration of creo-

[1] H. F. Weiss, "Structure of Commercial Woods in relation to the Injection of Preservatives," *Proceedings of the Eighth Annual Meeting of the American Wood Preservers' Association*, 1912, pp. 158–187.

sote in dense woods and in heavy 'summer wood' of long-leaf pine paving blocks by the fact that the dense tissue cracks more in drying. Such splitting, he says, does not occur to the same extent in the light, thin walls, as they seem to yield and bend more under the readjustment of the wood during drying. The heavy walls, it seems, therefore, cannot readily adjust themselves to moisture changes, and consequently split somewhat in the manner of a tie when it dries too rapidly.

"The objections to Tiemann's hypothesis which have been outlined above are equally significant in this case. However, as a special test of this theory, Professor Bailey states that he examined the wood of long-leaf pine paving blocks in which the penetration of heavy creosote oil and tar oils was confined almost exclusively to the dense bands of 'summer wood.' The secondary walls of the 'summer wood' in the majority of cases were found to be unruptured. 7, fig. 25 illustrates a cross section of the 'summer wood' of a very dense specimen of long-leaf pine. The heavy secondary walls are seen to be devoid of drying cracks (compare 4, fig. 25). Since greater penetration occurs in unruptured as well as ruptured bands of 'summer-wood' cells, the phenomenon must be due to some undetermined factor.

"*Certain structures easily confused with drying cracks.*—In those portions of the stem and branches of coniferous trees which are called upon to resist heavy stresses in compression a highly specialized type of tissue, according to Professor Bailey, is laid down by the cambium. This tissue is structurally designed to resist compression. The inner and thicker part of the secondary wall of its component cells or tracheids is composed of very fine more or less closely approximated spiral bands. In longitudinal or cross sections of dry wood these cells might

easily be mistaken by the unsuspecting observer for cells whose walls had developed numerous fine cracks or 'slits' in drying. However, as is shown in 5, fig. 25, a longitudinal section of freshly cut green white pine sap-wood taken from the immediate vicinity of the cambium, these structures are not a concomitant of drying or seasoning, but are fine screw-like bands deposited upon the inside of the cells by the protoplasm. This specialized tissue is called 'Rothholz' by European investigators.

"6, fig. 25 is a photomicrograph of a longitudinal section of air-dried loblolly pine sap-wood, and illustrates a condition which occurs in air-dried hard pine from the southern United States. The striated or cracked appearance has not been produced by shrinkage of the cell walls in drying, but is the result of incipient stages of decay. The minute mycelium of the fungus travels spirally within the thick secondary walls of the 'summer wood,' gradually dissolving the wall substance by its enzymes or ferments. Seen under magnifications such as are commonly used in studying woody tissues, these spiral cavities, in longitudinal sections of the wood, might easily be mistaken for drying cracks. However, by using thin sections and high-power oil-immersion lenses, the structures are seen to be produced by a wood-destroying fungus. In cross section the secondary wall is seen to be not cracked as in 4, fig. 25, but drilled by numerous small circular burrows which contain the dried mycelium of the fungus.

"The following summary and conclusions have been arrived at by Professor Bailey:

"1. Spiral cracks in the walls of tracheids and fibres occur in only a small percentage of dry wood.

"2. Spiral cracks, when present, are confined in coni-

ferous woods to the heavy, thick-walled tracheids at the end of the year's growth.

"3. Spiral cracks are confined to the secondary and tertiary layers of the cell wall, and the primary wall remains unruptured.

"4. Air passes as easily through dry cells whose walls are unruptured as through cells whose secondary walls have cracked in drying.

"5. In many cases air cannot be passed through dried cells whose secondary walls possess well-developed 'slits,' or cracks.

"6. Although drying cracks or 'slits' do not close when dry wood is thoroughly re-soaked, re-soaked wood is in many cases as impervious to air as unseasoned material.

"7. Although air cannot be forced through long pieces of green coniferous wood even under heavy pressures, it passes in many cases through short pieces of more than one fibre length.

"8. In long-leaf pine paving-blocks, when the penetration was confined largely to the dense bands of 'summer wood,' the walls of the latter were, in the majority of cases, found to be unruptured.

"From this it is held to be clear that Tiemann's 'slit' hypothesis cannot account for the penetration of gases and oils into seasoned woods. Similarly, Weiss' theory cannot account for the greater penetration of preservatives into dense tissues. In both cases some undetermined factor, or factors, are at work which control the injection phenomena.

"Fig. 25 shows at 1 a radial longitudinal section of a western hard pine showing spiral cracks or 'slits' in the thick walls of the 'summer wood' (Sr.). The thin-walled spring tracheid (Sp.) at the right is seen to be unruptured,

×400. 2, a cross section of the dense fibres of a broad-leaved tree, or 'hardwood,' showing drying cracks in the thick secondary walls. The darker coloured primary walls which enclose the inner layer are seen to be unruptured, ×500. 3, a tangential longitudinal section of the 'summer wood' of western yellow pine showing spiral cracks or 'slits,' ×500. 4, a cross section of both the 'summer' (Sr.) and 'spring wood' (Sp.) of a Mexican hard pine. The cracks or 'slits' are confined to the thick secondary walls of the 'summer wood.' The dark primary walls are seen to be unruptured, ×500. 5, a longitudinal section of freshly-cut white pine sap-wood, taken from the immediate vicinity of the cambium, showing the fine spiral bands which occur in specialized cells that resist compression, ×700. 6, a longitudinal section of loblolly pine tracheids, showing striated effect produced by incipient stages of decay, ×1000. 7, a cross section of the air-dried 'summer wood' of a very dense specimen of long-leaf pine. The thick secondary wall, as well as the primary and tertiary walls, are seen to be unruptured (compare 4). The first faint lines crossing the section from right to left were made by the minute irregularities which occur on the edge of even the sharpest microtome knife, ×500."

The Structure of the Pit Membranes in the Tracheids of Conifers.

Dealing with the structure of the pit membranes in the tracheids of the conifers and their relation to the penetration of gases, liquids, and finely divided solids into green and seasoned wood, Professor Bailey[1] con-

[1] Contributions from the Laboratory of Wood Technology of the Harvard School of Forestry.

tributes the following particulars : "The xylem or woody portion of arborescent plants has three important functions. It conducts large quantities of water, with gases and salts in solution, from the roots to the cambium and leaves, provides a strong and rigid stem which lifts the foliage to a position when it can secure desired amounts of air and light, and serves as an important reservoir for the storage of elaborated food substances. The structure of wood has been evolved to fulfil these functions, and varies greatly in different species, and even in the same individual, with variations in the expression of these functions. In the less complex woods the same elements serve in more than one capacity, but in those which are more highly organized a division of labour takes place and certain elements act principally as conductors of water, whereas others have almost, if not entirely, ceased to act in that capacity. It is quite clear, therefore, in studying the water-conducting passages of wood, as a means of securing information in regard to the behaviour of preserving fluids when injected into timber, that one must consider, to some extent at least, other functions which this tissue is called upon to perform.

"If we turn to the microscopic examination of the wood of coniferous trees or 'soft woods,' which is less complex than that of the higher seed plants or 'hardwoods,' we find that the woody tissue is composed largely of minute vertically arranged elements or tracheids which are devoid of living contents. These cells, resembling minute tubes with closed tapering ends, are a fraction of a centimetre long and serve the double purpose of conducting fluids and providing strength and rigidity to the stem. In accomplishing the latter object the cells are provided with a thick, heavily lignified wall, the so-

called secondary wall, which is completely enveloped by the thin primary wall. These layers or walls surround an elongated cavity or lumen through which fluids pass on their way to the leaves. It is quite obvious, however, that provision must be made for enabling fluids to pass easily and rapidly from the cavity of one cell into that of adjoining cells. The dense secondary wall, although hygroscopic, is not easily permeable to solutions, and is therefore provided with numerous pores or minute open-

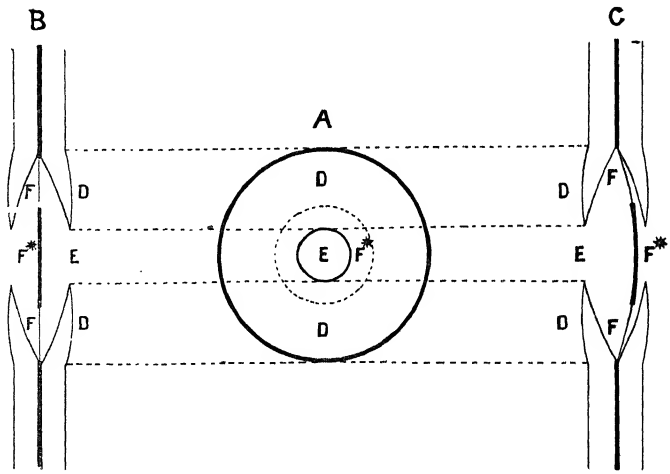


FIG. 26.—Diagram showing structure of bordered pit.

ings called bordered pits. Since these structures are of fundamental importance in the penetration of liquids through woody tissues, it is essential to examine them with considerable care.

"A circular area of the secondary wall surrounding the minute opening or pit orifice is embossed or pulled away from the primary wall, forming a saucer-shaped blister which projects into the cavity of the cell. In the surface view (*see* A, fig. 26) this area forms a halo or border (D)

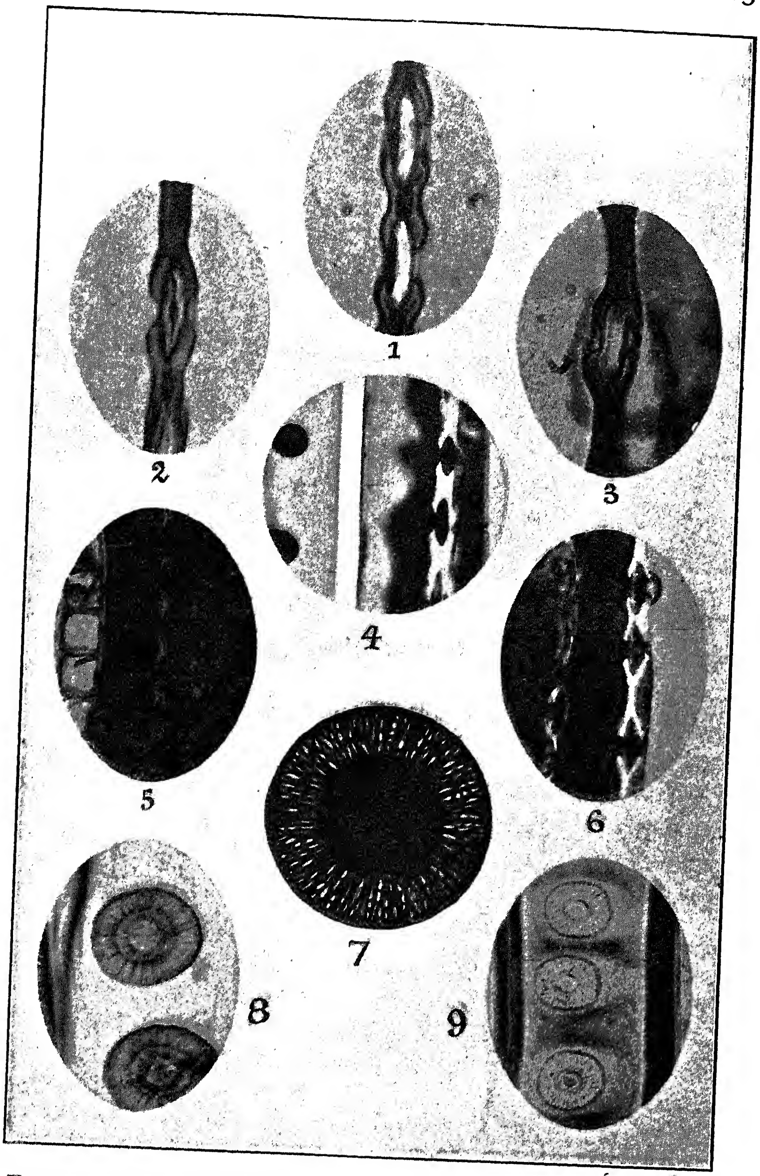


FIG. 27.—Photomicrographs showing the structure of pit membranes in conifers.

about the opening (E) in the secondary wall. The bordered pits of adjacent cells are exactly opposite to one another and form a row of lens-shaped cavities (*see* 5 and 6, fig. 27) which communicate with the cavities of the two cells by means of the two openings (E) in the adjacent walls. Communication between the two cells is interrupted, however, by the primary walls, which in this region become very thin and form a delicate membrane (F) which divides the lens-shaped cavity into two plano-convex cavities (B, fig. 26). The dividing membrane possesses a circular thickened area (F*) called the torus, which acts as a valve. Before sufficient pressure can be brought to bear upon the delicate membrane to rupture it, the torus is forced to one side or the other, sealing more or less effectively one of the openings in the secondary walls (*see* C, fig. 26, and also 1 and 3, fig. 27).

"The necessity for these delicate and complicated valve-like structures is seen when it is taken into consideration that water, in passing from the roots to the leaves of a tall tree, must pass through a large number of minute cells which are less than a centimetre in length. Not only must the aqueous solutions pass through a large number of cell walls, but at times they must do so comparatively rapidly. The bordered pit is designed, therefore, to expose a relatively large surface of very thin, permeable membrane without seriously impairing the strength and rigidity of the secondary wall.

"*Detailed structure of the pit membrane.*—It is a commonly accepted fact among physiologists and anatomists that in conifers the wood cells or tracheids are entirely enclosed in the thin primary membrane. In the region of the bordered pits the 'primary wall' may be greatly reduced in thickness, but although very permeable to water containing salts and gases in solution, it is supposed to be impervious

to undissolved gases and finely divided solids, and more or less impervious to heavy oils and other heavy or viscous liquids. This conclusion, that the primary wall or membrane is unperforated even in the region of the bordered pits, is based upon two lines of evidence. Careful microscopic examinations have failed to reveal perforations in pit membranes. (Russow, Nägeli, Strassburger, and others discovered that the pit membrane was not homogeneous throughout, but frequently composed of fine alternating radial bands of thinner and thicker wall substance. They concluded, however, that the membrane was unperforated.) In addition, numerous experiments in injecting freshly-cut green wood with water containing powdered solids and heavy liquids, e.g., Sach's cinnabar and mercury experiments, have led to the same conclusion, that the pit membranes are entire in the wood of a living tree.

" This fact afforded, apparently, a satisfactory explanation of the difficulty in forcing air through green wood; the use of salt solutions, but not creosote, in the Boucherie and kyanizing processes; the necessity for preliminary steaming or seasoning in the Bethell process, etc., etc.

" The question may well be raised at this point, since Tiemann's 'slit' hypothesis cannot be accepted as conclusive, what structural change, if any, produces the difference in the behaviour of green and seasoned wood? It occurred to Prof. Bailey that the delicate pit membranes were ruptured by the shrinkage of the cell walls in drying. To determine conclusively by microscopic examination whether the pit membranes are ruptured in a given piece of seasoned timber is difficult, since it is not easy to eliminate the possibility that the ruptured condition was produced by the process of sectioning. However, by embedding material in nitro-cellulose and subsequently

cutting sections with a very sharp microtome knife, Prof. Bailey was able, in large measure, to overcome this difficulty, and to determine that in many pieces of seasoned wood the pit membranes had been ruptured by the shrinkage of the cell in drying. In order to test this point experimentally he injected the thoroughly air-dried wood of several conifers with an aqueous mass containing very finely divided particles of carbon held in suspension. Obviously this dark-coloured liquid could penetrate only when actual openings existed in the cell walls. Subsequent examination of the material revealed the interesting fact that the penetration from one cell to another occurred entirely through the bordered pits. 5, fig. 27, a longitudinal section of air-dry sequoia heart-wood, illustrates the penetration of the carbon particles from one cell to another. The tracheid in the centre of the photomicrograph is entirely filled with the dark-coloured mass. The carbon particles are passing through the chain of bordered pits into the adjacent cell cavity on the right. It may be noted that the bordered pit in the centre of the photomicrograph is partly filled with a resinous substance and slight penetration occurs. At the extreme left is a so-called 'medullary' ray, which, with carbon particles of this size, remained unpenetrated. 6, fig. 27, illustrates a tangential section of the 'summer wood' of an ordinary long-leaf pine paving-block. Since the heavy tar oils had penetrated almost exclusively the dense bands of 'summer wood,' it is significant, in view of Weiss' theory, that the penetration from one cell to another takes place by means of the bordered pits, and not by cracks or 'slits' in the thick secondary walls.

"As a 'control' for these experiments Prof. Bailey tested the penetration of the carbon mass with pieces of freshly-cut green sap-wood. A deeper and easier penetra-

tion was secured in green material of white pine, pitch pine, spruce, hemlock, larch, and cedar than could be secured in the same material after thorough kiln or air-drying. In both cases the material was subjected to similar temperatures (18·3°C., 65°F.), pressures, and duration of treatment. At first negative and positive pressures of approximately one atmosphere were used. In order to obviate the possibility that the membranes were ruptured by these pressures, two series of tests were made. In the first, experiments were made to determine at what pressure the pit membranes could be broken. With pressures up to 250 lb. per sq. in., the maximum capacity of the pressure cylinder used, the membranes of all conifers remained unruptured. This was undoubtedly due to the valve-like action of the torus which has been described earlier (*see* C, fig. 26, and 1 and 3, fig. 27). A second series of experiments was then made to test the penetration of the carbon mass under very slight hydrostatic pressure. Hartig showed that if a stick of freshly-cut green sap-wood several inches long was held in a vertical position and a drop of water placed upon the top, it disappeared very quickly and appeared at the lower end of the stick. Prof. Bailey repeated this experiment, connecting the upper end of the stick to a rubber tube of a few cubic centimetres' capacity. If a sufficiently dilute solution of the carbon mass was used the water passed rapidly through the stick carrying the carbon particles with it. 4, fig. 27, a longitudinal tangential section of freshly-cut green white pine sap-wood, shows the carbon passing from one tracheid to the next, through the membranes of the bordered pits. On the left two tangential pits filled with carbon are seen in surface view. 8, fig. 27, illustrates a radial section of the same wood under high magnification. The carbon particles are seen to penetrate the membrane

in a rim about the torus and in lines radiating outward from it. Thus the Professor was forced to the conclusion that the pit membranes in the tracheids of living coniferous trees are not entire as has previously been supposed, but are perforated by extremely minute openings, which are located in the thinner radii of the membrane.

"The next step was to subject coniferous woods to a microscopic examination to determine if these perforations were visible under the highest power of the microscope. This proved a difficult undertaking owing to the minute size of the structures under observation. Special methods of sectioning and staining were essential owing to the peculiar structure of the bordered pits. However, fairly satisfactory results were finally secured by cutting exceedingly thin sections (2 micra). In this way it was possible to cut away one of the embossed areas of the secondary wall, exposing to view the membrane and torus. By careful staining and the use of very high magnification, the detailed structure of the membrane could in many cases be successfully studied. 7, fig. 27, illustrates in a diagrammatic manner the structure of the pit membrane. In the centre is the thickened portion of the membrane or torus. Surrounding the torus is the thin, permeable portion of the pit membrane. This is seen to be composed of alternating bands of denser and thinner membrane substance. The perforations are located in the thin, lighter-coloured radii of the membrane. They are extremely variable in size, and may in certain species increase in size or coalesce to form larger and more conspicuous openings. 9, fig. 27, illustrates an unusually coarse type of perforation which sometimes occurs in the wood of the larch.

"It may well be asked, in view of the perforated structure of the pit membranes, why it is that gases cannot be

forced easily through long pieces of green wood and through many specimens of thoroughly re-soaked dry wood. This is, I believe, due to capillary or surface-tension phenomena combined with the valve-like structure of the bordered pits. If we have an aqueous solution on both sides of the pit membrane shown in 2, fig. 27, and the molecules or minute particles of water are set in motion by a slight pressure, they are free to pass easily and rapidly from one cell to another through the perforations in the pit membrane. Now let us suppose that we force air into either of the cells. The water will be gradually driven out until the air comes in contact with the pit membrane. As soon as this happens the surface tension of the water in the minute openings of the membrane resist the further penetration of the air. When additional pressure is applied to force the water from the perforations this membrane is forced to the side and the torus seals, more or less effectively, the opening in the secondary wall (*see* 1 and 3, fig. 27). If a very short piece of wood is used so that the air has to penetrate only one or two membranes, it is sometimes possible to pump air through green wood. On the other hand, if there are numerous membranes to be encountered, capillarity or surface tension and the valve-like structure of the tori effectively prevent the penetration of air, even under heavy pressures. The fact that re-soaked dry wood is, in many cases, somewhat less impervious to air than unseasoned material is probably due to the rupturing of the pit membrane during the process of drying.

"Summary and conclusions:

"1. Wood is a highly specialized and complex plant tissue, designed primarily to conduct aqueous solutions and to give strength and rigidity to stem and branches.

"2. It is extremely variable in different species and

even in different parts of the same individual, due to variations in the functions which it is called upon to perform.

"3. Coniferous woods, or 'soft woods,' are composed largely of minute cells, or tubes, with closed ends. Liquids, in passing through this tissue, travel primarily in the cavities of the cells, and pass from cell to cell by means of delicately constructed valves or bordered pits in the cell walls.

"4. The membranes of the bordered pits are not always entire, as has been previously supposed, but possess (in all species examined) numerous minute perforations, whose presence may be demonstrated by careful microscopic examination and by experimental means.

"5. When wood is thoroughly dried, no structural modification, such as the rupturing of the cell walls, is essential in order to account for the penetration of gases and preservatives into seasoned wood.

"6. In green wood, the bordered pits and membranes are very permeable to aqueous solutions, but are comparatively impervious to undissolved gases, and to oils and other heavy or viscous liquids. This is due, undoubtedly, to capillary or surface tension phenomena and the valve-like action of the torus.

"7. Dry wood (except when the cells are clogged with resins or other secretions) is very permeable to gases, since water is no longer present to resist the passage of the gases through the perforations in the pit membranes.

"8. Whenever preservatives are injected rapidly into green or seasoned wood, the penetration takes place primarily through the cavities of the cells, and the preservatives pass from one cell to another through the bordered pits.

"9. Rupturing of the pit membranes was found in some

specimens to be concomitant of the process of drying, and may account for the fact that in certain cases re-soaked dry wood is less impervious to air than green material.

"10. The impregnation of wood by modern commercial methods is a complicated chemical, physical, and anatomical problem, since any given phenomenon may be the result of numerous interesting chemical, physical, and anatomical factors.

"Fig. 27 shows at (1) tangential section of sequoia showing sectional view of the bordered pits. The membrane and torus are seen to occupy a medium position between the two arching cell walls, × 1,200. (2) Tangential section of hard pine showing sectional view of bordered pits. The tori have been pressed against the left-hand orifices by excessive pressure, × 1,000. (3) Tangential section of hard pine showing sectional view of bordered pits. The torus in this case is thin and flexible and has been jammed into the right-hand orifice so firmly that it appears bow-shaped, × 1,000. (4) Tangential section of freshly-cut green white pine sap-wood injected with a carbon mass. The minute carbon particles are seen to penetrate from one cell to another by the bordered pits, × 700. (5) Tangential section of sequoia heart-wood showing the penetration of carbon mass from one tracheid to another through the numerous bordered pits, × 500. (6) Tangential section of the summer wood of a common long-leaf pine paving-block. The heavy tar oils are seen to penetrate by means of the bordered pits, × 600. (7) Diagrammatic drawing of pit membrane and torus. The perforations are seen to occur in the thinner bands of membrane substance, × 3,500. (8) Radial section of freshly-cut green white pine sap-wood treated with a carbon mass. The carbon particles are seen to penetrate the pit membrane in a rim about the torus, and in lines

radiating outward from it, × 1,500. (9) Radial section of larch showing large perforations in the pit membranes, × 800."

Note.—With the exception of Fig. 7 these illustrations are "unretouched" photomicrographs.

Fig. 28 shows a magnified section of beech wood. This illustration is taken by permission from a publication by Messrs. Richard Wade, Sons & Co., Limited, entitled

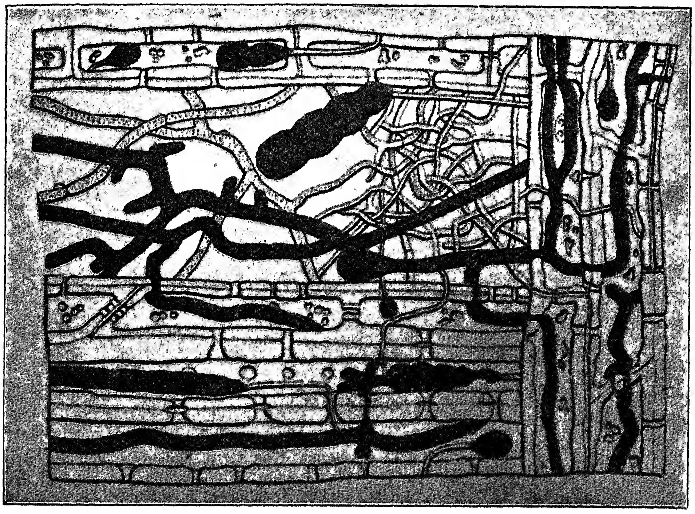


FIG. 28.—Magnified section of Beech Wood.

Creosoted Wooden Poles for Electrical Power Transmission, Telegraph, Telephone Work, etc.: Their Strength and Use, which work contains much interesting and useful information. The illustration (Messrs. Hulsberg & Co., Berlin) in question is instructive as showing the way in which the destroying fungus spreads through timber by the thin filaments or thread-like bodies known as hyphœ.

Laboratory Analysis after Treatment *v.* Actual Record during Treatment.

In a paper read at the annual meeting (1915) of the American Wood Preservers' Association, by Mr. Frank W. Cherrington, entitled "Laboratory Analysis after Treatment, versus Actual Record during Treatment of Creosoted Wood Paving Blocks," the author makes the following statement: "Owing to the remarkable variation in the structure of wood it is only possible to accurately determine the average quantity of creosote oil injected per cubic foot of timber by close observations of the proper treating gauges, and automatic recording devices, at the creosoting plant during the actual process of treatment. The composition of the timber is of so complex a nature that scarcely two wood paving-blocks are identical in structure, even when cut from opposite ends of the same plank of average commercial length. This is true, regardless of the most careful commercial specification as to lumber, limiting the percentage of heartwood, number of annual rings to the inch, etc. Therefore, although treated under the same temperature and same pressure, scarcely two wood paving-blocks will have the same degree of penetration or absorption." The following are given as some of the reasons for this variation in structure: "Some of the blocks are necessarily manufactured from timber coming from the heart of the tree, and some from the exterior portions of the tree. The oven dry weight of the sap-wood is often but two-thirds that of the heartwood. A cross-section of a tree cut from its base will be an entirely different structure from the cross-section cut from the middle or top. Timber growing on the side of a hill will be different from that growing on high or low ground. Some trees will grow

at the edge of the forest and others in the interior. A piece of timber cut from the north side of a tree will show a different structure from that cut from the south side. A rapidly growing tree will have a different structure than that of a slow growth timber of the same species. Thus it is seen that environment is largely responsible for the complexities in the wood structure of a tree."

A writer in Bulletin 101 of the Forest Service, United States Department of Agriculture, referring to the relative resistance of various conifers to injection with creosote, says: "It is very difficult and sometimes apparently impossible to secure uniform treatment of wood with preservatives. If, for example, an average treatment is given of ten pounds of creosote per cubic foot, some pieces of wood in a charge will receive twice the average amount, while others will receive less than half of it."

From the above Mr. Cherrington considers that the selection of a dozen or so of blocks from a carload of some 15,000 individual blocks for analysis by the chemist can only be unsatisfactory. And besides, he observes that the final result obtained from laboratory analysis is liable to be in error. The human element, volatility of the creosote oil, difficulty in separating the injected creosote oil from the natural resin, impossibility of extracting all of the injected oil, etc., etc., all tend to reduce the precision of the result. The possibility of an error in laboratory extraction and analysis, combined with the variation of the wood structure, doubles the chance for inaccuracy and detracts from a precise estimation of the average amount of creosote oil initially injected into the wood.

When some blocks amongst a large number treated at the same time show a less penetration, it is generally safe to assume that those blocks are incapable of taking

up the oil on account of their pores being already filled with resin, and it is said that such blocks have never given any trouble in practice.

In concluding this chapter an observation made by Mr. Howard F. Weiss, Director, Forests Products Laboratory, Madison, Wis., in a communication to the *Journal of Industrial and Engineering Chemistry,* may be appropriately quoted, viz., that "the depth to which oils can be impregnated varies as some inverse function of the viscosity."

CHAPTER V

The Preservative Treatment of Wood (continued)

The Open Tank or Immersion System : Efficiency of—Apparatus required.

The open Tank or Immersion System.

THE open tank or immersion system of impregnating wood with a suitable antiseptic or preservative solution is carried out in two ways. The first or simplest method consists in steeping the timber in a cold solution of the preservative in a suitable tank until such time as the wood has become sufficiently impregnated.

The hot process requires the provision of a furnace to enable the temperature of the antiseptic solution in the tank to be raised to the desired point. The antiseptic most frequently employed in the open-tank or immersion system is creosote or dead oil of tar, but many other preservatives are available.

The open-tank hot or boiling creosoting process allows of two steeps a week being made. The creosote oil should be heated up to 93°C. (199·4°F.) for 8 to 10 hours, the whole of the working day, and allowed to cool during the night. This operation is repeated the next day, and when the creosote oil is quite cool the timber can be extracted.

The open-tank cold process occupies from nine to eighteen days, the time taken in absorbing the agent depending greatly upon the species of timber being treated. In both of the above processes especial care is necessary to see that the timber is thoroughly dry before treatment.

Efficiency of Open-tank System.

Regarding the efficiency of the open-tank method of preserving wood, Mr. Rowe observes that sleepers, and any wood that will make a good paving-block, must be well dried before it can be properly impregnated by this method, and this seems to be the secret of success. Mr. Card, of the Chicago Tie and Timber Preserving Company, states that the open-tank method of creosoting will undoubtedly produce good results if it is confined to the treatment of blocks, shingles, posts, etc., or, in other words, small dimension lumber, and it will not be successful in this case unless the utmost care is taken in the seasoning of the lumber before treatment. As regards the treatment of sleepers by this method, he says that a loblolly pine sleeper, provided it is thoroughly seasoned, would probably absorb the greatest amount of solution in the least time, but any other class of sleeper treated on the open-tank method would take from two to three weeks to absorb the same amount of solution that could be injected under 100 lb. pressure per square inch in 4 hours' time.

The process is used to a considerable extent in the United States for treating the butts of telegraph poles, and is stated to be found suitable for treating cypress and various kinds of pine.

Apparatus for Open-tank Process.

The plant required for carrying out the open tank process, which is the oldest method of applying preservatives, is simple and inexpensive.

Fig. 29 shows an apparatus for steeping wood by the hot process. The plant consists of a steeping tank, a storage tank, pump, drain cock, funnel, furnace fittings, and the necessary piping. The steeping tank is rectangular in shape and fitted with a flat bottom. It is constructed of

mild steel $\frac{1}{4}$ inch thick, and strengthening bars are provided down the sides and along the bottom in suitable positions. The rivet seams are so placed as to suit the flames from the furnace, and the entire tank is riveted, caulked, and tested for boiling creosote. An angle flange is also riveted round the top edge of the tank, and holding-down bars are provided.

The tank is mounted as shown upon a brick furnace having a cast-iron door and frame, and a set of fire-bars and front and back bearers are provided. At the rear end of the furnace is a funnel made of mild sheet steel of No. 10 W.G., having a square base at its bottom end for mounting on the brickwork, and a flap damper fitted on the top.

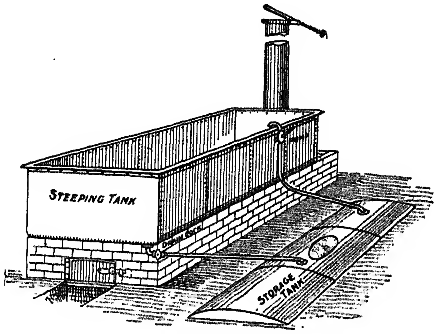


FIG. 29.—Tank for steeping timber by the hot process.

At the side of the steeping tank, and partially sunk in the ground, is a storage tank for the preservative or antiseptic solution. This tank is built of mild steel and is cylindrical in shape, and is, as will be seen from the illustration, placed below the level of the steeping tank. It is provided with a manhole and strainer through which the antiseptic solution is inserted. A double-acting semi-rotary Wing pump is bolted to the side of the steeping tank with a delivery bend discharging into the latter, and a suction pipe fitted with a foot-valve leading into the storage tank. At the front end of the steeping tank and at the bottom corner nearest to the storage tank is fixed a drain cock with

bend flange and pipe connected with and discharging by gravity into the storage tank.

The above apparatus is designed by Messrs. George Black & Sons, Berwick-on-Tweed, and is made by them in various standard sizes ranging from the smallest which has a steeping tank 12 ft. 6 in. in length by 5 ft. in width by 3 ft. in depth, and having a storage tank with a capacity of 800 gallons, to the largest having a steeping tank 20 ft. in length by the same width and depth, with a storage tank a capacity of 1,200 gallons.

Where steeping in cold solution is practised, the apparatus used is similar except that the furnace fittings and funnel and brickwork flues are dispensed with.

Another pattern of open steeping tank is one constructed with doors at one or at each extremity. The door or doors can be closed and form a fluid-tight joint or joints when the wood to be treated is in the tank, and the charge of antiseptic or preservative solution is admitted. In this arrangement of steeping tank a line of rails can be fixed in the bottom and the wood to be treated run in and out on trucks.

CHAPTER VI

The Preservative Treatment of Wood (continued)

The Pressure System: Advantages of the Pressure System—Points to be Considered in Carrying out Impregnation—Fundamental Points to be Considered in Plans of Wood Preserving Works—Examples of Standard Plants Working on the Pressure System—Tram Cars for Charging Retorts—Wheels and Axle Boxes for Cars—Bail Fastenings for Cars—Bumpers or Buffers—Coupling Links and Hooks—Examples of Complete Cars—Prices of Charging Cars—Loading and Unloading Charging Cars—Hydraulic *v.* Air Pump for Forcing Preservatives into Retort.

The Pressure System.

THE chief objects to be aimed at are: firstly, to ensure as thorough a saturation as possible with the preservative solution of the entire portion of the wood capable of saturation; secondly, to introduce into the wood only sufficient solution to effect the above object; and thirdly, to so introduce the solution as to cause no injury to the wood.

Advantages of the Pressure System.

Where a considerable quantity of timber has to be treated and time is naturally a matter of primary importance, the pressure system is the most suitable. The time occupied in treating a charge of wood in a pressure cylinder or retort is only about as many hours as the number of days that would be taken to impregnate a charge of wood on the hot or boiling immersion system in an open steeping tank, and the cold immersion system occupies almost as many weeks. The advantages of the pressure system, moreover, are more marked when hard woods have to be treated.

Points to be Considered in carrying out Impregnation.

The preparation of the wood consists essentially in the extraction of the liquids and semi-liquids which constitute the immature portion of the wood, and are contained in the interstices between the fibres, without softening the cement binding of fibrillæ or bundles of cellulose tissue which form the solid or fully-matured portion of the wood. The above operation removes all those portions of the tissue which are liable to fermentative action, and the value of artificially-preserved wood depends entirely upon its successful accomplishment.

The amount of pressure to which the wood is subjected in the retort during impregnation is a matter of considerable importance. A high pressure tends to expedite the operation, but it must not be overlooked that too high a pressure is liable to cause injury to the fibre of the wood, by forcing in more of the agent than the natural voids can hold.

The general opinion amongst experts seems to be that pressures of from 100 lb. to 180 lb. per square inch are the most advantageous, the higher pressures being required for creosote oil and the lower for other agents. Besides injury to the wood, over-pressure also causes a considerable waste of the agent, as when an amount of the latter in excess of the absorptive power of the wood has been injected, the surplus will waste out after the wood has left the retort and be lost. A considerable pressure in the retort, even as high as 300 lb. per square inch, may not at first affect the strength of the fibres of the wood to any appreciable extent, but it may be the cause of serious consequences in after years.

Should the treatment be carried out at too low a

temperature, or for too short a period, only the sap or liquid part nearest the surface will be removed, and the space receiving the preservative agent will not be sufficient. Conducting the operation at too high a temperature, or for too long a period, on the other hand, will result in the resinous portion of the bundles of fibrillæ becoming softened and the elasticity of the wood being reduced in a proportion corresponding to the decrease in the coherence of the fibrillæ. According to the practice of the Norfolk Creosoting Company, U.S.A., the temperature should never be less than 100°C. (212°F.), or exceed 130°C. (266°F.).

The absorption of preservative during the filling and heating, or initial absorption period, has been found to be least when no preliminary vacuum or air pressure was used, and greatest when high preliminary air pressures were used. The time required to fill the retort generally varies from about 20 minutes, when preliminary vacuum is used, to about 40 minutes, when a preliminary air pressure of 75 pounds is used.

Of the two possible methods for the removal of the undesirable portions of the timber, viz. exposure to currents of dry air; and steaming under pressure, with an after-drying in a vacuum, the latter is recommended as the best practice. Although the first method would seem to be the least likely to modify injuriously the physical structure of the wood, in actual working this is found not to be the case. With proper manipulation, a more thorough desiccation, without harmful change of the organic structure, can be accomplished in twelve hours less by the latter process than is ever possible with air drying, which, under the most favourable circumstances, is a long drawn-out operation, and, in any case, cannot do more than extract the water from that portion of the sap

which has not yet reached the semi-solid stage, thus leaving in the tissues of the wood a very considerable amount of resinous matter, which occupies space that should be ready to receive the preservative agent. The consequence of this is a failure of the oil to reach many of the interfibrous passages, which are either left empty or are filled with the gelatinous part of the half-matured growth cells in which are to be found the conditions that make putrefaction possible. In order to remove the sap from wood, it is first necessary to vaporize it and then to bring about such external circumstances as to allow of the outflow of all gaseous matter from the interior of the wood. To vaporize the sap it is necessary to break down the walls of the cells containing the liquid and the semi-liquid substances. This can be readily accomplished through the agency of heat applied through the medium of a moist steam bath at such a pressure as to keep the temperature of the wood and its surrounding atmosphere somewhat above the boiling point of the sap. The maintenance of this condition for a few hours is said to be found to be quite sufficient to break down the sap-cell tissue, and to vaporize all those constituents that it is desirable to withdraw. This point having been reached, the steam bath is discontinued, and the temperature being maintained at, or slightly above, the vaporizing point of the sap, the pressure of the atmosphere surrounding the wood within the retort is reduced below that of the interior of the wood. The result of this condition would be an overflow of vapour and air, continuing until equilibrium was restored. This equilibrium is prevented by the use of an exhaust pump until the absence of aqueous vapour in the discharge from the pump indicates the completion of the operation. At this stage the tissue is in a state very like that of a sponge cleared of hot water,

every pore is gaping open and ready to receive the agent.

With regard to the value of preliminary steaming, the following opinion is expressed in a report of the Committee on Miscellaneous Subjects to the American Wood Preservers' Association at the tenth annual meeting held at New Orleans January 1914. The report is of considerable interest as it appears to settle the question as to the prevailing American practice, and that, moreover, from ascertained facts, and not merely from theories. The following are the conclusions and recommendations arrived at:

"1. All efficient plants should be equipped to steam material when occasion requires, and the best method of introducing and distributing steam in the retort or cylinder is by means of perforated pipes.

"2. Steaming of ties, timber, and lumber is apparently not injurious to the wood, if the work is conducted intelligently and within certain limits of temperature and duration.

"3. It is difficult to inject any considerable quantity of preservative into green ties and timbers unless given a preliminary steaming or boiling in oil. One of the principal factors influencing the absorption of any kind of preservative is the moisture content of the wood—the dryer the wood the more it will absorb, consequently the more thorough the treatment.

"4. The object of steaming is to put the wood in a condition to secure the maximum penetration with the desired amount of preservative, and admits of the immediate treatment of green or fresh-cut material.

"5. Theoretically, steaming of green material preliminary to air-seasoning should materially reduce the period for air-seasoning.

"6. A maximum steam temperature of 138°C. (280·4° F.) should not be exceeded.[1]

"The maximum steam temperature of 138°C. should not be maintained for a longer period than three hours. The maximum temperature of the steam should be reduced after a period of three hours to not more than 121°C. (249·8°F.), and maintained at this temperature, or less, for the remainder of the steaming period.

"7. Under like conditions, chloride of zinc will penetrate the wood considerably more readily than creosote oil.

"8. During the process of steaming a considerable amount of condensed steam remains in the wood, which to some extent resists the entrance of the fluid. The liberating of this condensation, after steaming, may be accomplished by subsequent drying in open air or in drying ovens.

'9. Inasmuch as it has been claimed to have been demonstrated in actual practice that lumber, given a preliminary steaming season in open air, or in drying kilns, in one-third less time than is required when not steamed; therefore, we recommend that the Forest Service and members of the Association make tests and experiments during the current year to determine what influence steaming ties and timbers has on the rate of

[1] This temperature (280°F.) is also given for green or unseasoned timber in the "Report of a Committee on Plant Operation," American Wood Preservers' Association, 1915. In a report of a Committee on Specifications for the Purchase and Preservation of Treatable Timber, read at the same meeting, however, it is stated that the temperature in the treating cylinder should never be raised above 126·6°C. (260°F.) in steaming, nor above 93·3°C. (200°F). during oil immersion. In the boiling process it is considered that the oil temperature may be increased to 104·4°C. (220°F.). The minimum duration of treatment, except with easily penetrated woods, should, it is said, be equivalent to one hour for every radial inch on the sticks treated,

seasoning, when subsequently piled in open air or dried in drying ovens, keeping a careful record of details of the effects produced by preliminary steaming, and cost of same. Also conduct simultaneously a series of tests without preliminary steaming for purpose of comparison."

To ensure success requires most careful attention and skilful management, and, of course, the provision of adequate and suitable appliances. The attainment of a more or less perfect product demands the consideration of the following points: the wide divergence in the characteristics of timber; the varying amounts of sap due to the lapse of time since, and the season in which, the tree was felled; its possible subsequent immersion in water for a longer or shorter time; the character of the soil and the conditions under which the tree grew, whether in a dense forest or a comparatively open country; whether it is of a rapid, even growth, or of a slow, intermittent one. To an experienced operator these conditions indicate in each case the proper course to be pursued, and failure to observe and to take them into consideration is to invite indifferent, uncertain, and, in the end, unsatisfactory results.

Of almost equal importance is a proper understanding of the circumstances under which the finished product is to be used. Timber for piers, wharves, and other structures in tropical waters demand processes and degrees of thoroughness of treatment that are unnecessary in the harbours of more temperate climates, which latter are in turn more exacting than land and fresh-water constructions.

Ties or sleepers should be bored and adzed before treatment to ensure uniform bearing and maximum penetration under the rail seat. Although sawn ties may have a

uniform surface, the boring increases the penetration at the point where it is most needed.

A committee of the American Wood Preservers' Association, as the result of extensive inquiries, have arrived at the following conclusions as to the preliminary treatment of red oak ties :[1] (1) Red oak ties can be treated satisfactorily when air seasoned for ten months, if the summer months are included. (2) Red oak ties may be treated satisfactorily when air seasoned for six months, provided artificial seasoning is employed as an adjunct. (3) For practical reasons the period of seasoning, to determine whether red oak ties are ripe for treatment, should govern. (*a*) However, if boring test is used, the core withdrawn with an increment borer should appear dry for a depth of two inches. (*b*) If weight is used, the weight per cubic foot should not exceed 52 pounds. (*c*) If moisture determination is resorted to, a test should indicate not to exceed 22 per cent. of moisture in the ties. (4) Artificial seasoning of red oak ties apparently has not been sufficiently developed to justify a conclusion from the replies.

Fundamental Points to be Considered in Plans of Wood-Preserving Works.

The following points are given by Mr. Rowe as the result of extensive experience in the United States: "(1) That the works should be proportioned throughout to secure the desired output. (2) That each part should be proportioned to do the desired work, and at the same time so porportional to all the other parts that there will be no useless or surplus capacity or useless cost (3) That

[1] See also Appendix, page 298, table giving method of treating red oak ties that should be employed for different periods of seasoning.

each part perform its function in the most direct and in the simplest manner. (4) That every part be of the best manufacture, and the most reliable for lasting service, so that repairs will be infrequent, saving loss of time and expensive maintenance. (5) That the working parts be so arranged as to be promptly operated with the least manual labour. (6) That the plans of all the essential parts be fully planned and prepared so that there be no extra labour or delay during erection. (7) That the arrangement of the works be such that accurate measurements and weights shall be provided for, so that it shall be possible to know what is being done at any one time. (8) That the operator at the works shall be thoroughly competent, experienced, thoroughly honest and faithful, so as to be a safeguard between the two parties concerned."

In wood-preserving plants steam is usually used for operating the liquid and air pumps, the motive power of the hoisting apparatus for lifting loads, and of the hauling apparatus for moving loads on horizontal tracks; also for steaming the wood in the retorts, heating the oil in the latter, and in the storage tanks, heating the buildings in winter, etc. The economical use of this steam, and the consequent saving in the fuel bill, is therefore an important point. To this end it is essential in the first place to reduce the amount of work done by the machinery consuming steam to the lowest point consistent with efficient operation, and also to see that these machines are working at their highest rate of efficiency.

Care should be taken with respect to the air and liquid pumps that there are no leaks and that no higher pressures are carried than are necessary. In compressing air the quantity of steam used is dependent upon the volume of air handled, and upon the pressure against which the air is delivered. It is most important to see that an ample

supply of condensing water is available, so that the vapour is rapidly condensed, and the air pump has only to remove the vapour and air which cannot be condensed. Failing this, the air pump will have to boil out the steam and vapour by actual displacement, and not only will a much larger quantity of steam be required to drive the pump, but it will also take much longer to obtain the necessary vacuum. In extreme cases the time consumed may be as much as five or six times longer, and the loss be very considerable. Other sources of waste of steam are occasioned by the use of valves for draining coils instead of steam traps, by the bad condition of valves and pistons, by leaky slide valves, by insufficient cylinder lubrication, and from pipes unprotected or insufficiently protected by some suitable covering of non-conducting material.

A practice which is also very prevalent is to provide an elevated tank into which the water supply is pumped, the water required for use in the condenser being obtained from this tank. If a low service pump is provided to operate in conjunction with the condenser, for starting, this raising of the condensing water to an elevated tank may be dispensed with and a considerable saving effected, as the condenser will raise its own water to a reasonable height, without the assistance of any pump, directly the vacuum is created.

As regards the saving of fuel to be effected by the heating of feed water by exhaust steam, Mr. A. M. Lockett observes[1]: "All plants have heaters, but due to the fact that at the time the retort is under steam, at which time there is the maximum demand for steam, many of the auxiliaries are shut down, frequently there is not enough exhaust steam available to heat the water to the proper

[1] *Economised Use of Steam in connection with Wood-preserving Plants*, American Wood Preservers' Association, 1915.

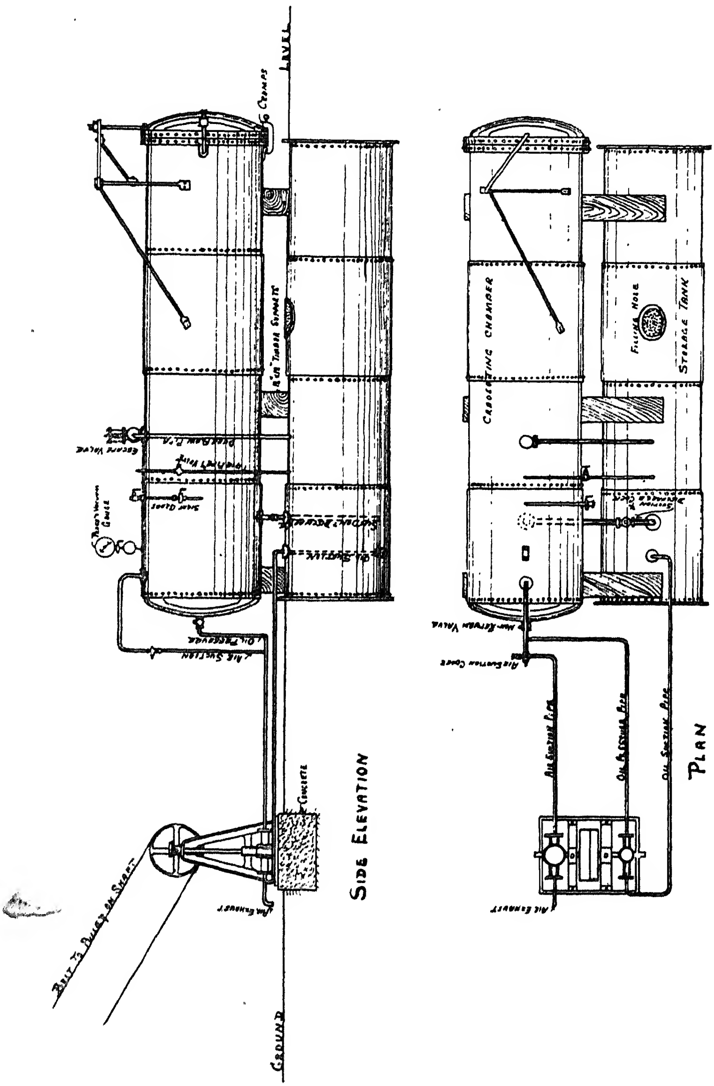
temperature. Not only can a substantial saving in fuel be made, but greater boiler capacity can be obtained by using a large covered and closed tank as an accumulator of hot water, this water being heated during the time that there is a surplus of exhaust steam."

The above are some of the directions in which important economies can be effected in the consumption of steam and consequently of fuel in wood-preserving works.

Examples of Standard Plants Working on the Pressure System.

Figs. 30, 31, and 32 show in plan and in side and end elevation a plant for treating wood on the pressure system having one cylinder or retort and suitable for use on estates or in small creosoting works.

The plant is designed and made by Messrs. George Black & Sons, of Berwick-on-Tweed. The retort or impregnating cylinder is built up of rings of the best mild double-crown boiler quality steel, placed alternately inside and outside, and riveted together in the same manner as a boiler. The door is strongly constructed and of cast-iron or mild steel according to the dimensions of the plant, and is carried by a wrought-iron crane bracket, which enables it to be easily swung open or shut. All edges of plates are planed, the rivet holes drilled by machinery after the plates are bent and in position, and the riveting wherever possible is done hydraulically, and the caulking with pneumatic tools. The impregnating cylinder or retort is fitted with the following connections: Suction and discharge cocks and pipe to storage tank; non-return check valve; gland-cocks for air and oil suction; wheel valve and pipe for admitting air to cylinder when discharging the creosote into storage tank;



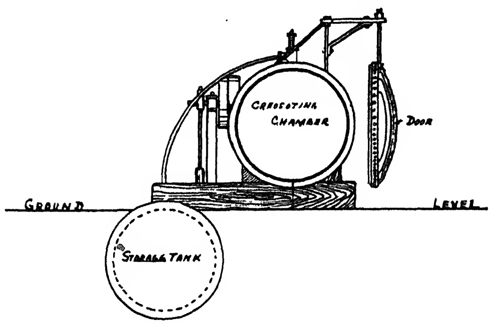
FIGS. 30 and 31.—Single cylinder pressure impregnating plant. G. Black & Sons. Plan and side elevation.

open spring confined flow escape valve with branch overflow. Compound pressure and vacuum gauge, cock

and syphon; and sight glass and cocks with glass guard mounted on pillar.

The storage tank, which has a capacity of 2,500 gallons, is cylindrical and, as shown, is placed below the level of the bottom of the impregnating cylinder or retort. It is constructed of mild steel plates ¼ in. thick with riveted joints.

There are two pumps, viz., a vacuum pump for exhausting the air from the impregnating cylinder after it is packed with timber and closed, and a force pump for pumping the preservative agent into the cylinder and maintaining it at the requisite pressure for the necessary time. Both these pumps are mounted on the one cast-iron foundation, and are designed to stand the continuous working pressure required. In the installation illustrated these pumps are belt-driven and provided with fast and loose pulleys and with belt striking gear.



FRONT END ELEVATION

FIG. 32.—Single cylinder pressure impregnating plant, G. Black & Sons. End elevation.

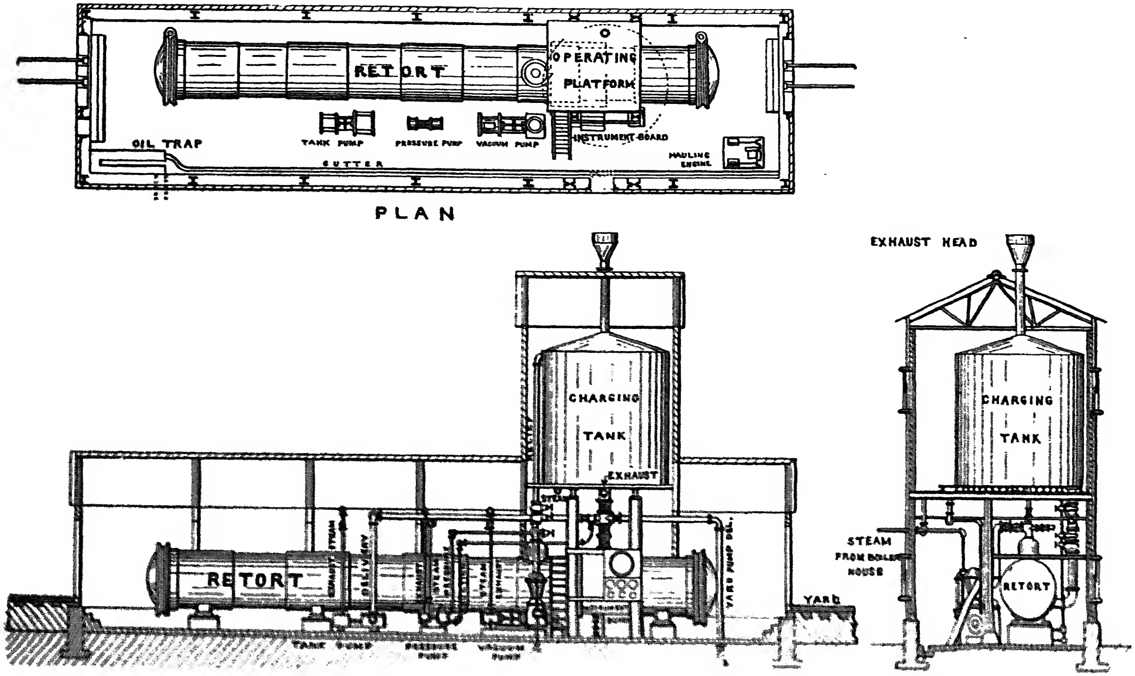
The power required for driving varies from 4 b.h.p. in the case of the larger pumps to 2½ b.h.p. for the smaller pumps. In the case of still larger installations the pumps are preferably steam-driven.

The operation of this plant is simple. After packing the impregnating cylinder or retort with timber to be impreg-

nated and closing the door, the air is exhausted by the vacuum pump, and the creosote oil is allowed to flow into the impregnating cylinder and is kept therein at the necessary pressure—from 100 lb. to 200 lb. per square inch—by the force pump for the required time, which varies, according to the nature of the wood, between two and three hours. The filling and emptying tap is then opened and the remainder of the oil allowed to drain back into the storage tank, after which the impregnating cylinder is ready for another charge. The capacity of the plant illustrated, with a cylinder or retort 5 ft. diameter by 20 ft. in length, is 450 to 500 fence rails, or about 350 posts.

The practice in the United States, in the case of what is usually known as the full-cell creosote process, is to employ a pressure of from 100 to 125 lb. per square inch, the wood fibres and cells of ties or sleepers being impregnated with from 6 lb. to 12 lb. of creosote per cubic foot, and piling with from 10 lb. to 20 lb. per cubic foot. Sometimes the wood is subjected to a vacuum at the finish to drain the surplus oil from the exterior of the wood and thus to prevent loss by drippage after the wood has been removed from the retorts. The time occupied in the treatment of ties or sleepers, omitting steaming, is 3 hours, including steaming 5 to 7 hours; time occupied in treating timber, including steaming, 7 to 11 hours; time occupied in treating piling, including steaming, 12 to 24 hours.

A simple installation, with one creosoting cylinder or retort, and necessary accessories, constructed by the Power and Mining Machinery Company, of Cudahy, Wis., U.S.A., is shown in plan, and in longitudinal and transverse sections in figs. 33, 34, and 35. This plant comprises one steel creosoting cylinder or retort; a steel charging tank placed at a level above the retort, and also storage measuring and underground tanks, not shown in



PLAN

LONGITUDINAL SECTION

CROSS SECTION

FIGS. 33, 34 and 35.—Single cylinder pressure impregnating plant. Power and Mining Machinery Company. Plan and longitudinal and cross sections.

the drawing; tie block and bolster cars for handling the timber in and out of the retort; vacuum pumps and condensers for withdrawing the moisture, sap, and surplus preservative; general service or tank pumps for transferring the preservative fluid from the tanks to the retort; pressure pump for injecting the preservative into the wood cells; centrifugal pumps for transferring the preservative, and for agitating the hot creosote oil; air compressor for blowing back the oil from the retort to the tanks, and for agitating and impregnating purposes; pumps for fire protection; feed pumps for

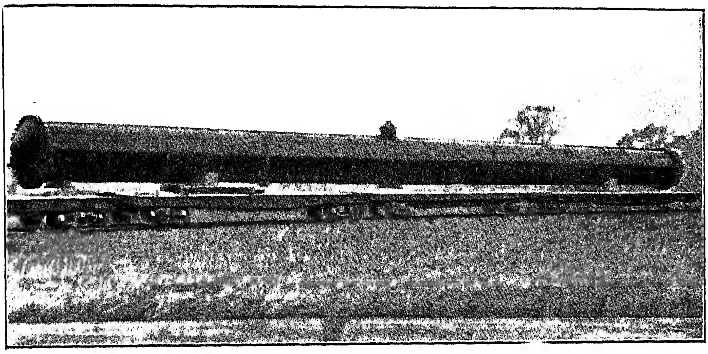


FIG. 36.—Retort or impregnating cylinder, 7 ft. dia. by 150 ft. in length, on trucks ready for shipment.

boilers; feed-water heaters, open and closed patterns, for preheating boiler-feed work. Also necessary boilers, buildings, hoisting engines, locomotives, generators, motors, requisite piping, valves, special fittings, thermometers, direct and recording pressure and vacuum gauges, multiplying float indicators, etc.

Obviously by multiplying the number of impregnating cylinders or retorts, and accessories, the plant may be increased to any desired capacity.

Fig. 36 shows a retort or impregnating cylinder 7 ft.

diameter by 150 ft. in length, on trucks ready for shipment. Retorts are made by the company up to 9 ft. in diameter. The cylinder is made of extra heavy steel plate to resist corrosion, and capable of withstanding a pressure of 200 lb. per square inch. It is fitted with cast-steel doors at one or both ends, and each course of the cylinder shell is made up of a single plate with the circumferential joints lapped and double riveted hydraulically with 1 inch diameter rivets, the seams being carefully caulked both inside and outside.

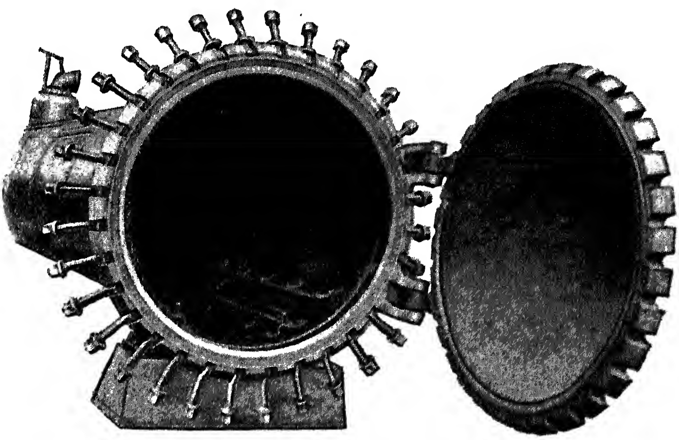


FIG. 37.—Perspective view showing tracks and guard rails inside cylinder.

Tracks are secured to the inside of the cylinder for the timber cars to run on, and guard rails are also fitted, as shown in fig. 37, to prevent the cars from floating and being derailed when the cylinder is filled with preservative solution.

The door and door frame are of cast-steel and fitted with swing-bolts, the lower hinge having a spring attachment, as shown in fig. 38, which prevents the door from

swinging back when opened, as in fig. 37. A dovetail seating is provided in the door frame for receiving gasket packing to form a tight joint.

The retort is provided with all the necessary pipe connections, made of cast-steel, for filling and discharging the oil, and steam coils are arranged in the bottom for maintaining the preservative solution at the proper

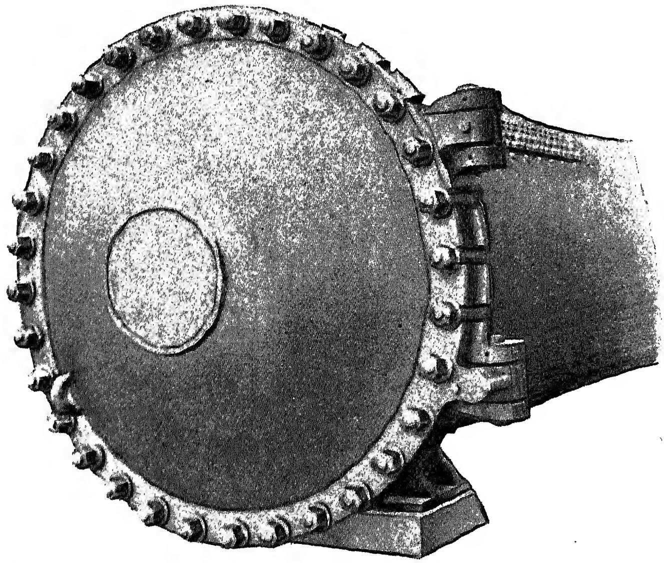


FIG. 38.—Perspective view showing arrangement of cylinder door, door frame, etc.

temperature. The retort is supported at one extremity on a massive cast-iron saddle and at the other end on a riveted expansion saddle which rests on a sole-plate. Intermediate supporting saddles made to fit the shell of the retort are also provided.

The charging tank is built of steel with closely riveted joints absolutely oil and water-tight, and being totally

enclosed the evaporation of the oil is reduced to a minimum. The tank is fitted with steam coils so as to maintain the contents at a proper temperature.

Fig. 39 shows a perspective view of the direct acting vacuum pump with jet condenser.

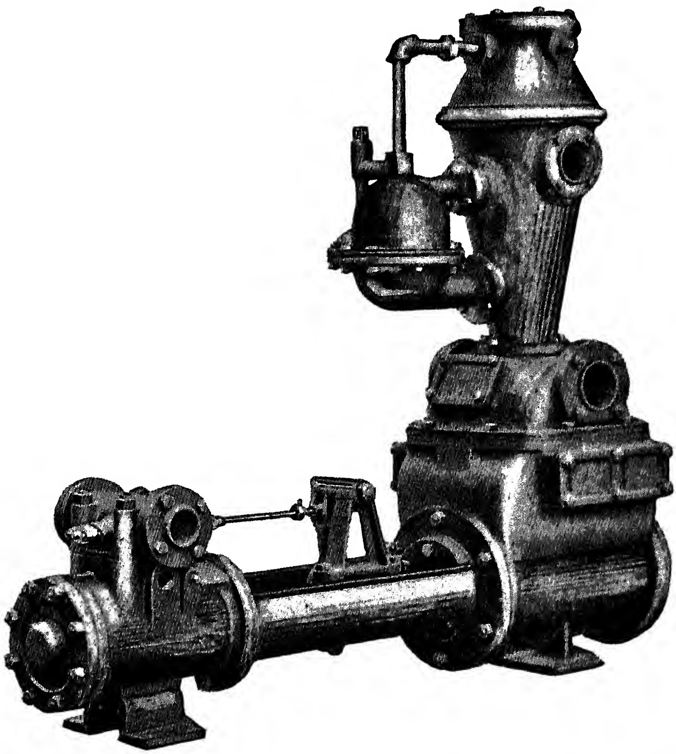


FIG. 39.—Perspective view showing direct acting vacuum pump with jet condenser.

The oil is delivered from the tank-cars into a receiving or dumping tank, from which it is emptied into the storage tanks. From these latter it is pumped into the charging tank situated (as shown in figs. 33 and 34) above the retort, and the oil is run into the latter by gravity.

To facilitate the rapid discharge of the retort, an emptying tank is preferably provided, from which latter the oil is pumped back into the charging tank. Air receivers and pressure tanks are also provided.

The vacuum pump, pressure pump, tank pump, heaters, etc., are of the well-known Worthington patterns ; or made by the Blake and Knowles Steam Pump Works, or by other well-known makers.

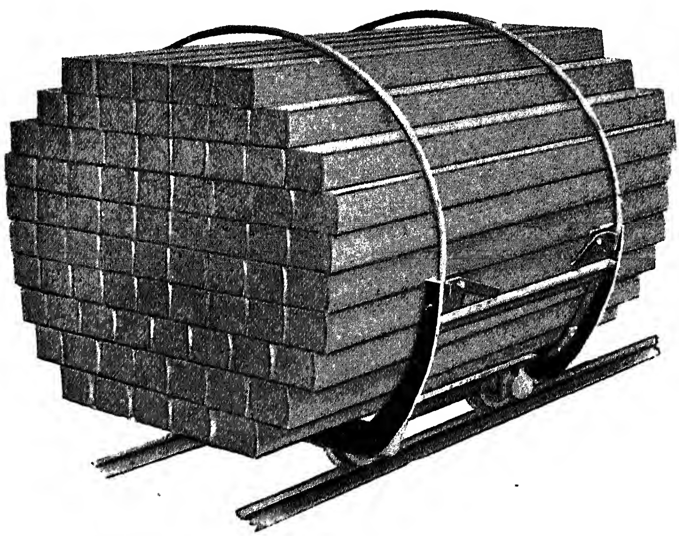


FIG. 40.—Perspective view showing sleeper or tie car for charging cylinder or retort.

Fig. 40 illustrates the special design of car for running ties or sleepers into the retort made by the company, and fig. 41 their wood paving-block car. The general construction of these cars will be seen from the drawings. Special attention is given in their design to prevent as far as possible distortion and the consequent fouling of the cars when they are run into the cylinders. The wheels

are made of chilled iron pressed on the axles, and the axle boxes are fitted with roller bearings. All the parts being formed in dies and drilled in jigs, perfect interchangeability is secured.

In the paving-block car special attention has been paid to the circulation of the oil. Hooks may be fitted for engaging the guard rail. The truck and bolster cars for piling and long timbers are of the patterns usually employed.

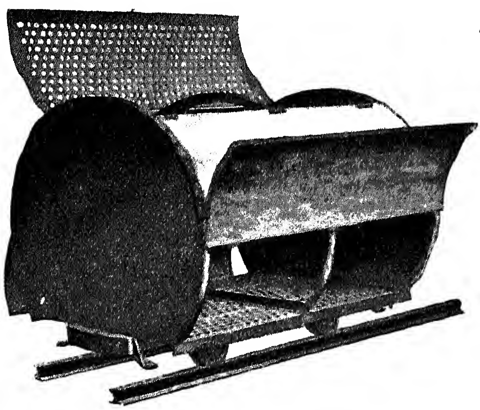


FIG. 41.—Perspective view showing wood paving-block car for charging cylinder or retort.

For details of construction of a number of different cars used in U.S. practice, see pages 150 to 171.

Fig. 42 is a perspective view, fig. 43 is a general plan, fig. 44 shows a longitudinal and figs. 45 and 46 show cross sections of a plant having a multiplicity of impregnating cylinders or retorts constructed and erected by the Allis-Chalmers Company at Somerville, Texas.

The commercial sizes of the retorts made by the above company are as follows: 72 ins. diameter and 74 ins. diameter by 42 ft., 52 ft., 108 ft., and 132 ft. in length; 84 ins. diameter by 108 ft., and 132 ft. in length; and 108 ins. diameter, by 132 ft., and 150 ft. in length. The shells of the retorts are made of the very best open-

hearth flange steel of thicknesses ranging from $\frac{3}{8}$ in. to 1 in., depending upon the diameter, working pressure, and preservative agent used, some of the latter causing rapid deterioration of the plates, whilst others have no injurious effect. The retorts are fitted with the usual rails and steam-heating coils for creosote.

The door of the retort is a most important detail. For low pressures the patterns recommended are, either a plain bolted one with slotted holes and ordinary tee-head

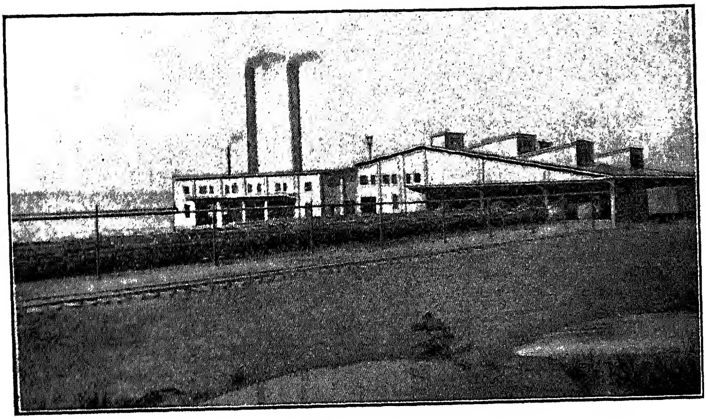


FIG. 42.—Multiple cylinder pressure impregnating plant. Allis-Chalmers Co. General view of works.

bolts, or what is known as a "spider door" with centre screw and lever nut arranged so that each lever has independent connection to the frame, such as that shown in front and side elevation in figs. 47 and 48. For high pressures an improved "spider" door, with centre screw and lever nut arranged so that the levers are connected to the frame by a continuous flange ring, would be found suitable; or a solid cast-steel bolted door with tee-head swing-bolts, such as that shown in front and side eleva-

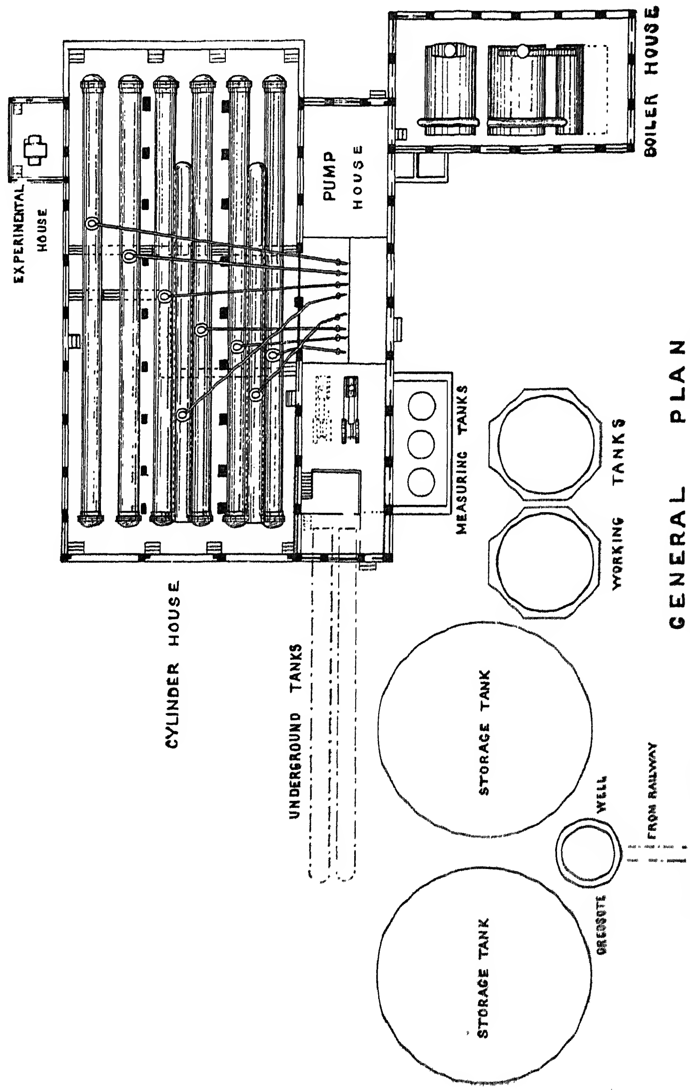
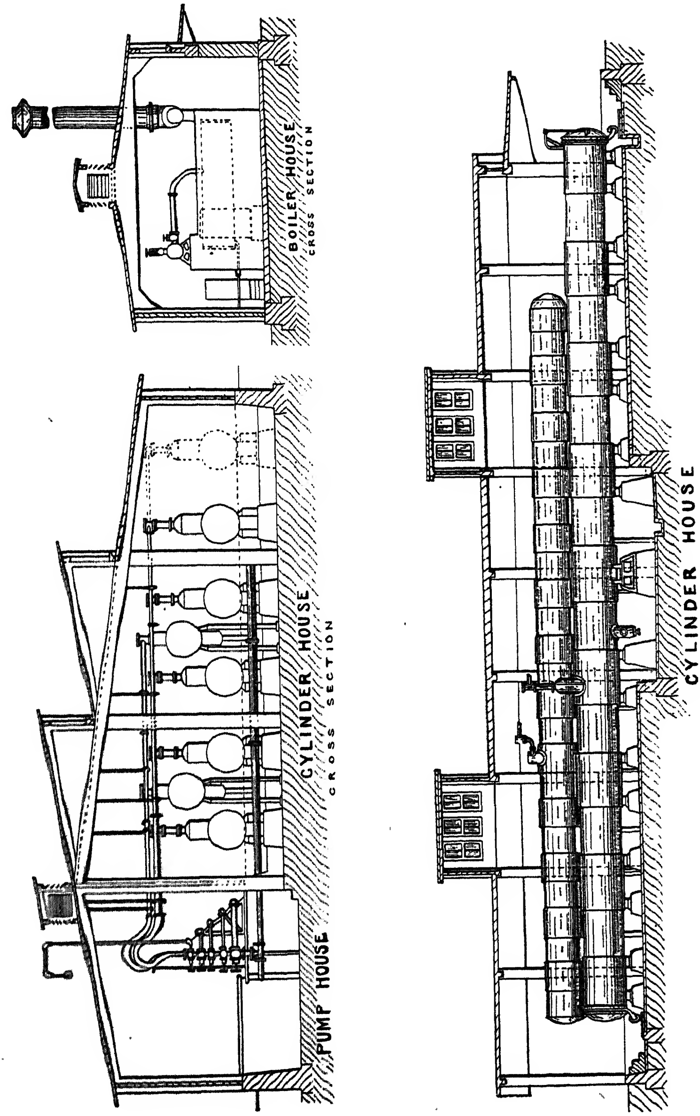
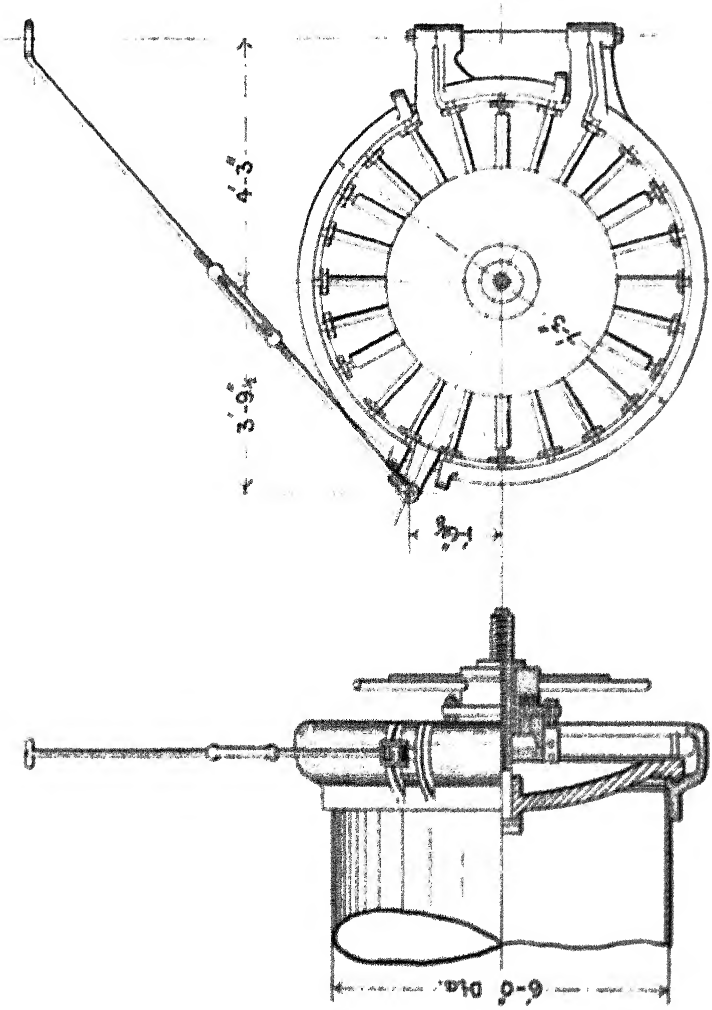


FIG. 43.—Multiple cylinder pressure impregnating plant. Allis-Chalmers Co. General plan.



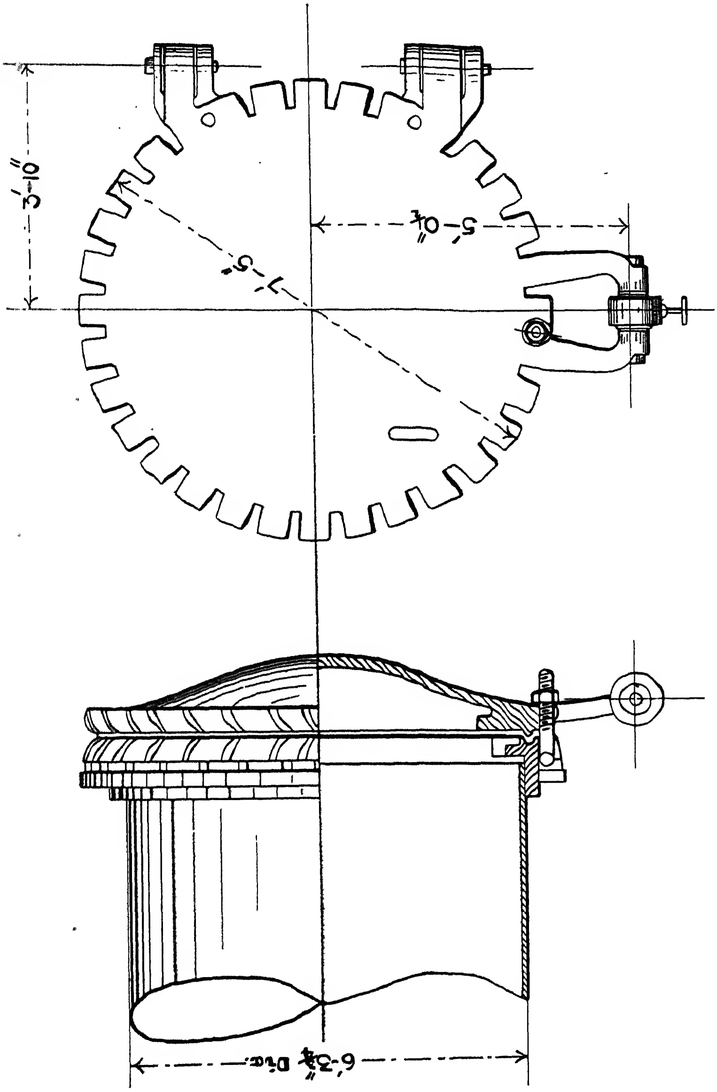
FIGS. 44, 45 and 46.—Multiple cylinder pressure impregnating plant. Allis-Chalmers Co. Longitudinal and cross sections.

tion in figs. 49 and 50 can be used. All the patterns of doors should have a projecting circular spigot on the door



Figs. 47 and 48.—Retort or cylinder door, spider pattern. Sectional side and front elevations.

which corresponds with a circular groove in the frame so that a sound joint can be formed by the insertion of a



FIGS. 49 and 50.—Retort or cylinder door, bolted pattern. Sectional side and front elevations.

gasket in the groove. This gasket is usually made of asbestos rope thoroughly dipped and painted with a

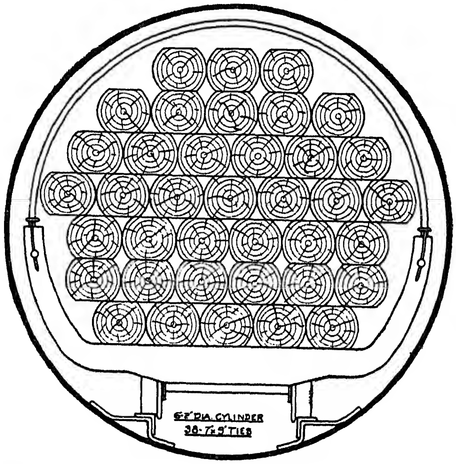


FIG. 51.—6 ft. 2 in. diameter retort, each car loaded with thirty-eight ties or sleepers. Cross-section.

mixture of graphite and oil. The retort is sometimes fitted with a door at each end.

The opinion of operators as to the best type of door varies, but it may be said that, in cases where time is an important factor, the "spider" door is probably the best as it can be opened and closed in about 2½ minutes, whereas the bolted doors occupy at least double that time. The bolted doors, however, have less parts, therefore they require less maintenance than the "spider" doors.

The capacity of the cars is a very important point on which the total output of the plant depends, and to obtain the maximum capacity for the tie car it is necessary that all the available space in the cylin-

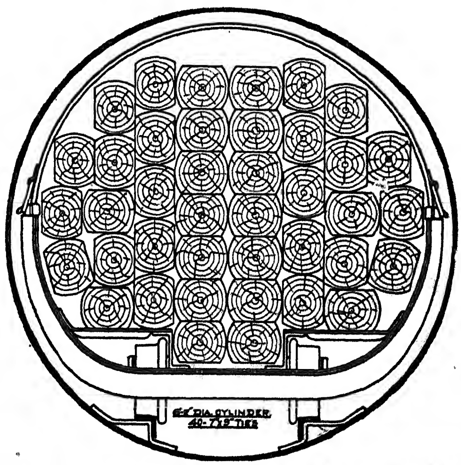
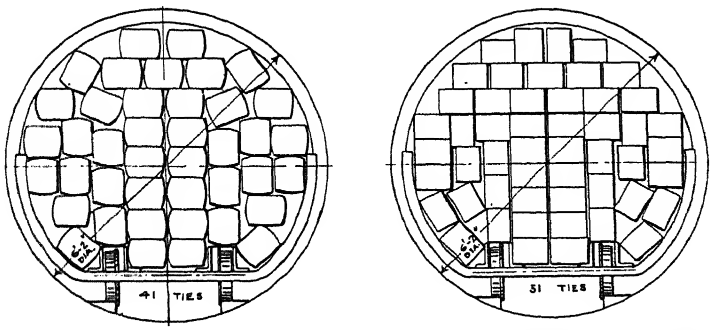
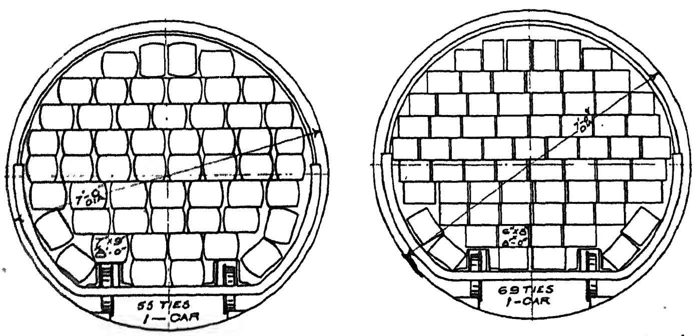


FIG. 52.—6 ft. 2 in. retort, each car loaded with forty ties or sleepers. Cross-section.

der or retort should be utilized for the placing of ties. Owing to the clearance space around the car, and the space required for the heating coils and the track, a certain amount of room is unavoidably lost. To minimise this



FIGS. 53 and 54.—6 ft. 2 in. diameter retorts charged, cars loaded with forty-one hewn and fifty-one sawn ties each respectively. Cross-sections.

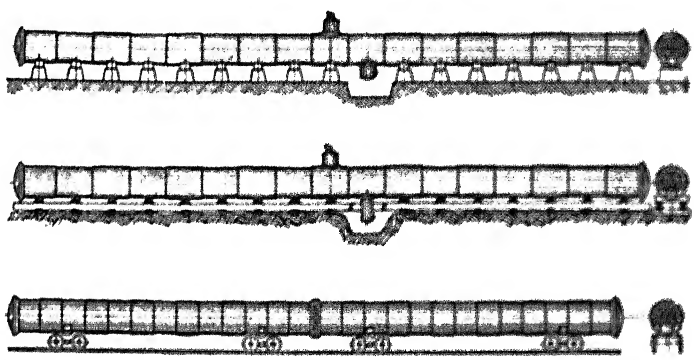


FIGS. 55 and 56.—7 ft. diameter retorts charged, cars loaded with fifty-five hewn and sixty-nine sawn ties respectively. Cross-sections.

loss cars have been designed which make use of the space between the wheels by which a gain of two ties is effected, which gives a considerable saving and consequently represents an important increase in profit during the year in the case of a plant having two treating cylinders holding a

charge of sixteen cars each and where from four to eight charges are made per day. Figs. 51 and 52 show the gain thus effected, the piling being only to demonstrate this fact and not being intended to show the actual methods adopted in practical working.[1] The usual methods of piling used are shown in Figs. 53 to 56.

Fig. 53 shows a 6 ft. 2 in. retort with each car loaded with forty-one hewn ties or sleepers. Fig. 54 shows a similar retort and car loaded with fifty-one sawn ties. Fig. 55



FIGS. 57, 58 and 59.—Stationary cylinder or retort on concrete foundations, ditto on wood foundations, and portable cylinder or retort mounted on standard gauge trucks. Side elevations and cross sections.

shows a 7 ft. diameter retort, each car loaded with fifty-five hewn ties. Fig. 56 shows a similar retort and car loaded with sixty-nine sawn ties. Fig. 57 shows a stationary retort mounted on concrete foundations, fig. 58 a stationary retort mounted on wood foundations, and fig. 59 a portable retort mounted on standard gauge trucks.

[1] "Tram Cars and their Construction," J. H. Grow. Tenth Annual Meeting American Wood Preservers' Association.

TABLE GIVING CAPACITIES OF PLANTS. *Allis-Chalmers Company.*

Size of Plants.			Capacity per year of 300 days. Treating Processes.					
			3 Charges to each retort per 24 hours. Burnettizing Wellhouse, Card and Full Cell.			4 Charges to each retort per 24 hours. Rueping and Lowry.		
[N]umber of [C]ylinders.	Cylinders. Diam. ins.	Cylinders. Length ft.	No. of Ties.	Cubic feet.	Thousand feet of lumber.	No. of Ties.	Cubic feet.	Thousand feet of lumber.
1	74	42	171,000	598,500	7,182	228,000	798,000	9,576
1	74	50	205,200	718,200	86,184	273,600	957,600	114,912
1	74	108	273,600	957,600	114,912	346,800	1,213,000	14,556
1	74	132	540,000	1,890,000	22,680	720,000	2,520,000	30,240
2	74	132	1,080,000	3,780,000	45,360	144,000	5,040,000	60,480
3	74	132	1,620,000	5,670,000	68,040	2,160,000	7,560,000	90,720
4	74	132	2,160,000	7,560,000	90,720	2,880,000	10,080,000	120,960
5	74	132	2,700,000	9,450,000	113,400	3,600,000	12,600,000	151,200
6	74	132	3,240,000	10,340,000	124,080	4,320,000	15,120,000	181,440
1	84	108	585,000	2,047,500	24,570	780,000	2,730,000	32,760
1	84	132	720,000	2,520,000	30,240	960,000	3,360,000	40,320
2	84	132	1,440,000	5,040,000	60,480	1,920,000	6,720,000	80,640
3	84	132	2,160,000	7,560,000	90,720	2,880,000	10,080,000	120,960
4	84	132	2,880,000	10,080,000	120,960	3,840,000	13,440,000	161,280

The width of the gauge of the cylinder track has also considerable bearing on the capacity of the cars. Mr. Grow states that practice has shown that a 24 in. gauge for a 6 ft. cylinder, and a 30 in. gauge for a 7 ft. cylinder, are the minimum widths. A 30 in. gauge for a 6 ft. cylinder and a 36 in. gauge for a 7 ft. cylinder could be used, but would reduce the capacity of the car, and it is questionable whether a wider gauge has any real advantages.

The above plants are primarily intended for the use of dead oil of tar or creosote as a preservative agent, but with slight alterations they can be adapted for the use of zinc chloride and other antiseptics.

Tram Cars for Charging Retorts.

The construction of the tram cars used for charging the retorts has received much consideration. The following abstract from a paper by Mr. Grow [1] gives descriptions of the various types of tram cars which are in use by some of the principal railway companies and commercial treating plants in the United States. Twelve different types of cars are described and illustrated, which may be conveniently divided into four distinct classes, viz., bar-arm cars, angle-arm cars, channel-arm cars, and cars with box-section arms. The angle-arm car is an improvement on the old type of bar cars. The channel arm car is a satisfactory construction provided it is braced properly. The best construction for car arms, however, is the box section. This gives the maximum

[1] "Tram Cars and their Construction," by J. H. Grow, Engineer, Wood Preservation, Allis-Chalmers Mfg. Co., Milwaukee, Wis., *Proceedings American Wood Preservers' Association*, Tenth Annual Meeting, January, 1914.

strength where the arm is bent and where it gives out, due to the weight and wedging of the ties.

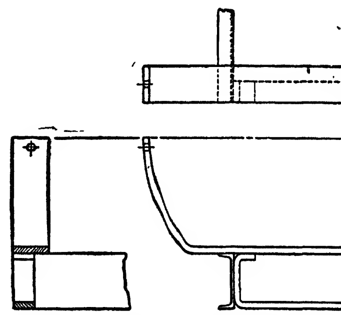


FIG. 60.—Car with channel frame braced with bar-iron and bar-iron arms.

"Fig. 60 shows the oldest type of construction which was used at some of the older treating plants. The frame or body of the car, to which the wheels are attached, is made of 8 in.—$16\frac{1}{4}$ lb. channels, braced at end with $\frac{3}{4} \times 2\frac{1}{2}$ in. bar-iron. In addition to this, cross braces of bar-iron are provided for the frames of the car. The car arms are made of 1×4 in. bar-iron. On some of the cars the bar-iron for arms was later on increased to 1×6 in. This is the weakest type of construction, and is also the cheapest.

"Fig. 61 is a later type of car. Each of the two side sills of the frame is made up of two $6 \times 3 \times \frac{5}{8}$ in. angle bars, braced at end with a pin and a short piece of 6 in. channel over the wheels. The arms are made of 6 in.—15·5 lb. channels, and are braced with two $1\frac{1}{2}$ in. angles back to back. At the point where the arms are secured to the frame small gusset plates are provided to increase the number of rivets for securing the arms to the frame.

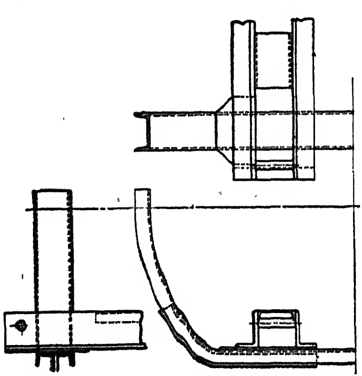


FIG. 61.—Car with angle-bar frame braced with channel and channel arms.

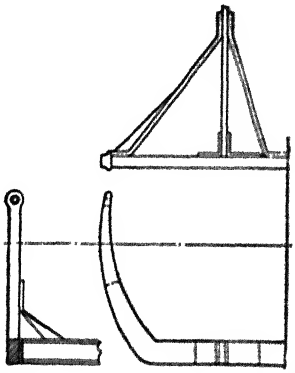


FIG. 62.—Car with heavy bar frame and solid bar arms.

"This later construction is superior to that shown in fig. 60. The strength of the frame is increased considerably and the arms are made more rigid with angle braces at the point where they are most apt to bend.

"Fig. 62 shows a type of bar car made of heavy bars throughout. The car frame consists of two 1 in. × 4 in. bars. Each of the bars is secured to the arm by two angles at either end. The arm is made of a solid bar 2 in. × 4 in., tapering from 4 in. at the point, where it is bent to about 1¼ in. at the top. Each arm is braced against the frame by means of two ¾ in. × 4 in. bars on either side. This car, being made of solid bars, gives good results when used in connection with the zinc chloride treatment. The arms have been designed to give the maximum strength where it is needed. The frame, however, is the weakest part of the car.

"Fig. 63 shows an angle-bar car. The frame is made of 6 in. × 6 in. angle and is secured to arms by proper connections. The arm is made from 6 in. × 6 in. angle, one flange, tapering from 5 in. at the point, where it is bent to 3 in. at the top. This car is now also made with a side brace connecting the two arms at the top, which prevents

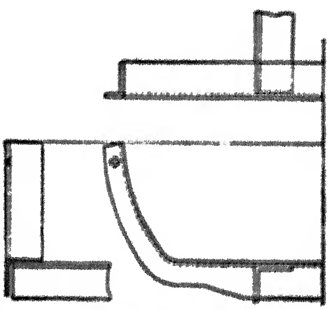


FIG. 63.—Car with angle frame and angle arms.

bending in a longitudinal direction.

"Fig. 64 represents another type of channel-arm car. The special feature of this car is the efficient bracing of the arm by means of a heavy T-rail. The arm is made of 7 in. channel, weighing 17·25 lb., and the brace is made in one continuous piece of 40 lb. T-rail. A gusset plate is used to connect the Z-bar frame to the arms, and the number of rivets for holding is thereby increased.

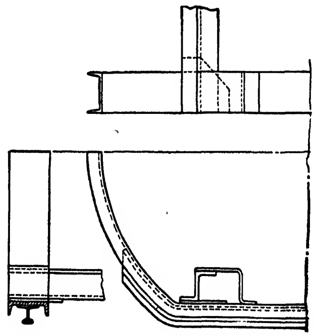


FIG. 64.—Car with channel arms braced with heavy T-rails.

"Fig. 65 shows a channel arm car. The two side sills of the frame consist of a pressed-steel hood made of $\frac{1}{4}$ in. steel. This hood covers up the wheels and makes a very strong and rigid frame. The car arms are made of 8 in.—21 lb. channel, and are reinforced by one continuous piece of 6 in. channel weighing $10\frac{1}{2}$ lb. The reinforcing channel is inverted so as to form a box section with the channel arms. At the end of the reinforcing channel a small casting is inserted, adding further strength. The hoods of the frame are secured to the arms by means of gusset plates. This design is equally as strong as that shown

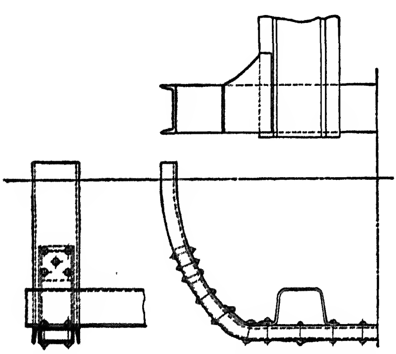


FIG. 65.—Car with frame consisting of pressed steel hood and channel car arms.

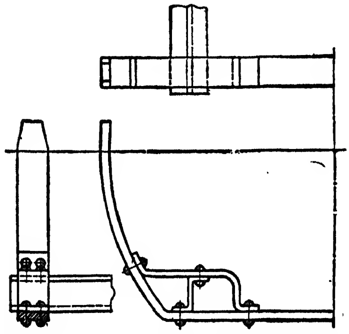


FIG. 66.—Car with frame of Z-bar and arms of bar-iron.

in fig. 64, having T-rails for reinforcing.

"Fig. 66 shows a new type of bar-arm car, which is an improvement over the old type of bar car. The frame consists of a 6 in. Z-bar, and the arms are made of $1\frac{1}{4}$ in. × 5 in. bar-iron. The arms are riveted to the Z-bar and the brace is attached so as to add strength and to secure the arm to the frame. This car gives good results at plants where zinc chloride treatment is used, since the solid bar offers less surface for the destructive action of the treating solutions.

"Fig. 67 shows another type of bar car. The frame consists of 6 in.—21 lb. Z-bar, and the arm is made in one continuous piece of $1\frac{1}{4}$ in. × 5 in. bar-iron. The arms are riveted to the Z-bar frame and are braced by a heavy bar, which is also riveted to the frame. Each brace is secured to the arm by means of four rivets. Excellent results have been obtained with this construction. It is a simple car of few parts, rigid and heavy.

"Fig. 68 indicates the general construction of a very heavy channel-arm car. The frame has two side sills, each made of two 6 in. Z-bars. The arms are made of heavy ship channels and are not directly reinforced,

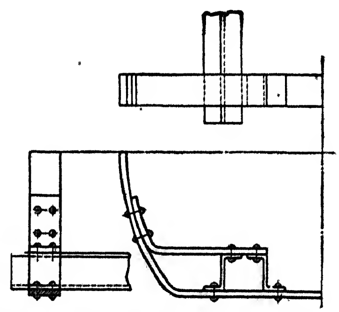


FIG. 67.—Car with frame of Z-bar and arms of bar-iron in one continuous piece.

but are strengthened by means of heavy gusset plates which are riveted to the top of the Z-bar frame and to the arm at the point where the maximum strain occurs. The arms are further braced in a longitudinal direction by means of a channel bar.

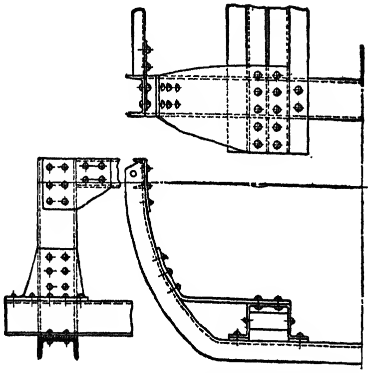


FIG. 68.—Car with frame of Z-bar and arms of heavy ship channels.

" Fig. 69 shows one of the later type of channel-arm cars. The two side sills of the frame consist of a pressed-steel hood, and the arms are made of channel bars, reinforced with a smaller channel. The reinforcing channel nearly extends over the entire length of the main channel. The frame is secured to the arms by means of large and heavy gusset plates.

"Fig. 70 indicates the general construction of a pressed-steel car. The frame of this car consists of two hoods made of pressed steel. The arm of the car has a box shape and is made from two steel plates. The lower or box shape is pressed out from one plate and to this is riveted the cover plate, making a very rigid arm. The arms are further reinforced by means of a strap riveted to the part where the maximum strain occurs.

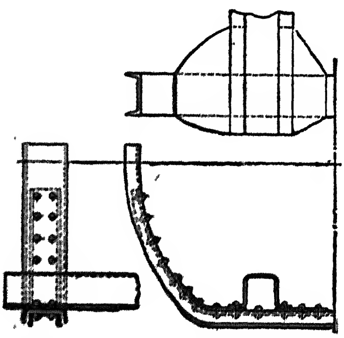


FIG. 69.—Car with pressed steel hood frame and arms of channel bar reinforced with smaller channel.

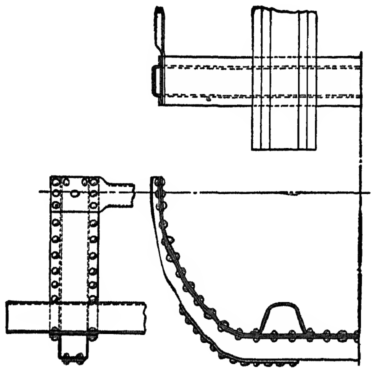


FIG. 70.—Car with frame consisting of two pressed steel hoods and box-shaped arms.]

The frame is directly riveted to the arms without the use of any gusset plates. The top of the arms are connected by means of a brace to strengthen them in a longitudinal direction. It will be noticed that the arm has a tapering shape, having the maximum section at the point where it is bent and the minimum section at the top of the arm. This construction is mechanically correct and has given excellent results in practice.

"Fig. 71 shows a new type of car with box-shaped arms and heavy bracing by means of gusset plates. The frame consists of two 6 in. Z-bars, to which are riveted the box-shaped arms. Each arm is made from two plates, the outer pressed into box shape, securely riveted together, forming a rigid construction. The box has a depth of 5 in. where it is bent and tapers to 3 in. at the top. The arms are further braced by means of heavy gusset plates riveted to the top of the Z-bars. Side braces connecting the two arms to prevent longitudinal bending are secured near the top. This car is

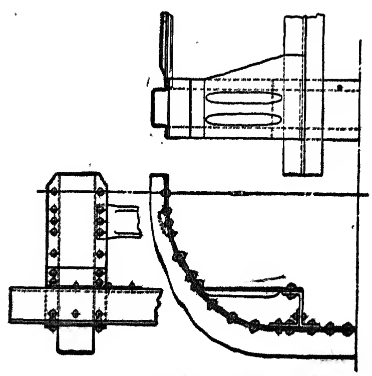


FIG. 71.—Car with frame consisting of two Z-bars and box-shaped arms.

especially well proportioned and provides ample strength in the arms and frame. It is one of the latest types and embodies all the experience obtained with the earlier cars, extending over a number of years.

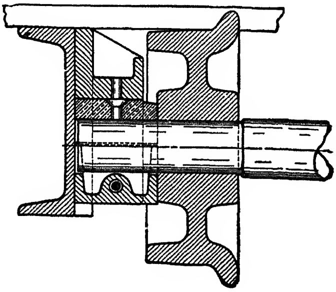


FIG. 72.—Car wheel used on the older type of cars.

WHEELS AND AXLE BOXES FOR CARS.

"The construction of the car wheel, roller bearing and boxes are very important factors. The shape and depth of the car-wheel flanges and the width of the tread are important details to be considered when designing a wheel, and should conform to the standard wheel construction, otherwise trouble will be caused by derailing. A great saving in motive power is effected by the use of roller bearings, two types of which are used—solid and spiral. The application of the above varies with the construction of the wheel, the bearing and the loads to be carried. Several of the more important designs are illustrated.

"Fig. 72 shows the arrangement used on the older type of cars. The wheel is pressed on the axle, turning in a brass. bushed bearing, to reduce friction. The bearing is bolted or riveted to the frame of the car.

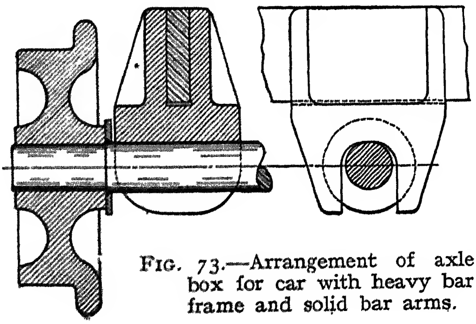


FIG. 73.—Arrangement of axle box for car with heavy bar frame and solid bar arms.

"Fig. 73 shows

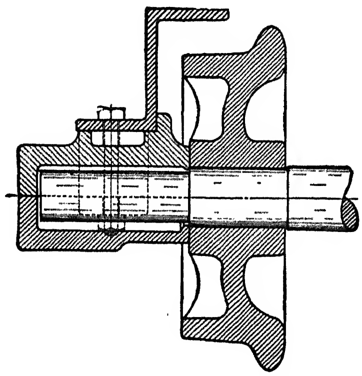


FIG. 74.—Arrangement in which wheel is fixed and the axle turns in bearing.

a novel arrangement for axle boxes, which is used in connection with car frame shown in fig. 62. This axle box takes care of the floating of the car frame when in treating cylinder, since it is not secured to the axle and slides up and down. The wheel is fixed and pressed on the axle.

"Fig. 74 illustrates another arrangement in which the wheel is fixed and the axle turns in the bearing. In order to reduce friction the upper half of the bearing can either be babbited or provided with brass bushing. This style of wheel and bearing is used with car frame shown in fig. 64, and makes a very good arrangement.

"Fig. 75 shows a roller-bearing arrangement in which the bearing is made of solid steel rollers and a steel bushing pressed into the wheel. The bearing is secured to the Z-bar frame, and the axle is prevented from turning by a bolt which passes through the end of the axle and the bearing. The wheels are separated by a pipe spreader, which encloses the axle and is fitted with heavy flange on each end. Wearing washers are provided to keep the rollers in place and to protect both

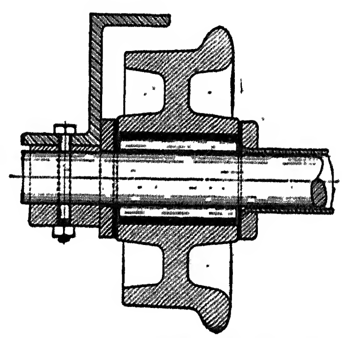


FIG. 75.—Arrangement of bearing with solid steel rollers and steel bushing.

sides of the wheel hub. This wheel and bearing is used with car frame shown in fig. 67, and makes a strong and serviceable car.

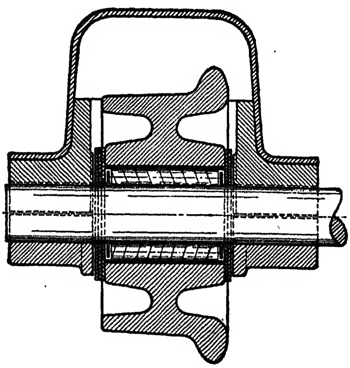


FIG. 76.—Roller bearing of the spiral type with heavy rigid bearing construction.

"Fig. 76 shows a roller bearing of the spiral type with heavy and rigid bearing construction. The spiral roller bearing is self-contained, or, in other words, all the rollers are held together in a small cage, and for this reason can be easily removed from the wheel. This bearing reduces the friction more than the solid roller bearing, thereby saving motive power. Unfortunately it cannot be used with satisfactory results at plants where the zinc chloride treatment is used, since the small spiral offers too much surface for the attack of solutions. It will be noted that the bearings on either side of the wheel are combined in one casting, which fits into the hood of the car frame, thereby securing the wheel rigidly. The axle is prevented from turning by clamping it to the bearing with caps. The wear on each side of the wheel hub is taken up by a series of

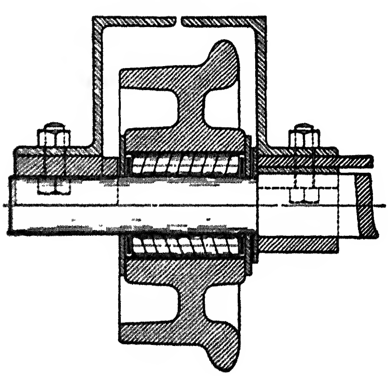


FIG. 77.—Spiral roller bearing with square axle turned down at the ends.

hardened washers. This style of wheel arrangement is used with car frame shown in fig. 65.

"Fig. 77 shows a spiral roller bearing used with the car frame fig. 68. It is to be noted that all previous arrangements show the use of a round axle, while fig. 77 shows the use of a square axle turned down at the ends. The car frame is secured to axle by a strap clamping the square part and preventing the axle from turning. A half-box is provided for the round part of the axle to distribute the load. The spiral roller bearing is of standard design. It should be mentioned that all the spiral bearings are furnished with slotted-steel bushing, which can be easily expanded into the bore of the wheel.

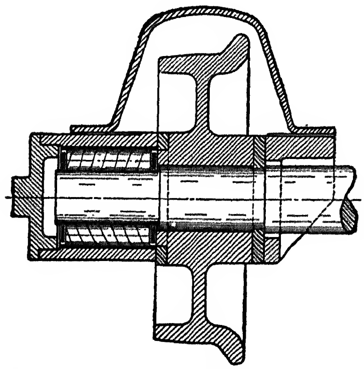


FIG. 78.—Arrangement comprising a combination of a turning axle with spiral bearing and a loose wheel.

"Fig. 78 shows an arrangement of special interest since it is a combination of a turning axle with spiral bearing and a loose wheel. The ordinary construction is to have either a turning axle with fixed wheel, or a fixed axle with loose wheels, but in this case this novel arrangement was designed to reduce friction as much as possible. The axle turns in the bearing secured to the car frame, and provided with spiral rollers to reduce friction due to the load. The loose wheels, which are provided with bushings, turn on the axle when the car is rounding a curve, and reduce friction between the outer rail and the wheel. The bearing box is in one piece and fastened to the underside of the car frame.

A cap screws into the end of the bearing to permit the removal of the spiral roller cage. The wheel is held in position by a casting which is attached to the car frame and which fits loosely over the axle. This wheel is used with the frame shown in fig. 70. The construction of this combination is very satisfactory, but it is, however, an expensive arrangement.

"Fig. 79 shows a wheel and bearing design which combines good construction with efficiency and convenience. It will be noted that the wheel is on the outside of the car frame, and can be removed without dismantling the car. This is an advantage, since wheels must be replaced sometimes. In all other designs shown above it is necessary to lift off the entire frame if a wheel or any of the wearing washers are to be removed. The axle, which is square and turned at the ends, is secured to the car frame by a wrought-iron strap. A collar is shrunk in the round part of the axle and shoulders against the square part to keep the wheel in proper position. The wheel is loose on the axle and is fitted with a standard spiral roller cage and split-steel bushing. The wear on the sides of the wheel hub is taken up by a set of hardened steel washers. A cap held in position with pin and cotter at end of axle secures the wheel.

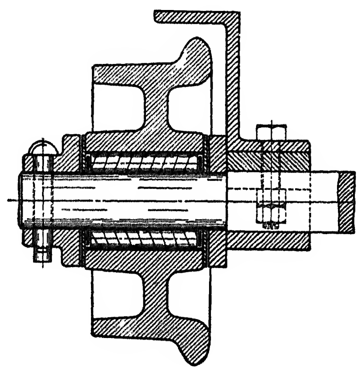


FIG. 79.—Arrangement in which the wheels are on the outside of the car frame.

A comparison of the eight arrangements of wheels

and axles show that they form two distinct types—wheels which are fixed or pressed on the axle, with the axle turning in the axle box, and wheels which are loose on the axle, with axle in a fixed position.

It will also be noted that the wheels shown are of heavy construction, with tread varying from 3 to 4 in. The average width is about $3\frac{3}{4}$ in., and has been found to be sufficient. This is a very important point, and especially in yards where heavy rails weighing 60 and 70 lb. are used together with standard frogs and switches. If a narrow wheel is used and the car slides over to one side in passing over the curve and switch, the flange of the wheel will strike the switch point and will derail the car. Briefly, Mr. Grow considers the essential points of good design are loose wheels of heavy construction with roller bearings and wide treads.

Bail Fastenings for Tram Cars.

The bail fastenings are an important feature of the tram cars, and they must be strong and so arranged that the bail can be removed quickly and easily. Five of the principal patterns described are as follows:

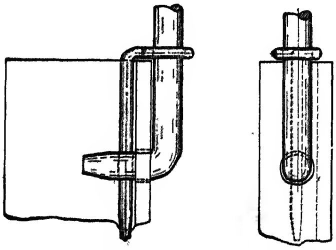


Fig. 80.—Simple arrangement of bail of round iron bent over at each end.

"Fig. 80 shows a simple arrangement. The bail is made of round iron $1\frac{1}{8}$ in. diameter, and is bent over at each end. The bent part engages the car arm and is held in position by a small locking pin fastened to the bail.

"Fig. 81 shows a round bail with straight ends each

of which fits into a socket riveted to the car arm and supported on a small angle. The locking pin cannot work out on account of its curved shape, and is inserted in a horizontal position and then turned down.

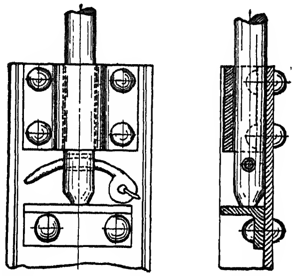


FIG. 81.—Round bail with straight ends fitting into sockets riveted to car arms.

"Fig. 82 shows a flexible connection which allows for any irregularities in the piling of the ties on the car. The bail is made of a square bar, and a wedge is attached at each end by means of a clevis and link. The wedge fits into a socket riveted to the arm and is locked in place by the wedge key.

"Fig. 83 shows a very simple and self-locking device. The bail is made of round iron $1\frac{3}{8}$ in. diameter, and is bent over on each end. The end is flattened out and is fitted with a pivoted pin of same diameter as the bail. When inserting the bail ends the pin is moved into a horizontal position, and falls into a vertical position by its own weight after the bail is in place, thereby locking it.

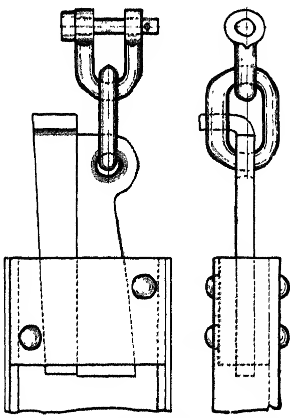


FIG. 82.—Flexible connection allowing for irregularities in the piling of ties on car.

"Fig. 84 shows the latest patented device for securing the bail to the arms. The bail is made of 1 in. × 2 in. tire iron and fits into a malleable iron socket riveted to the car arms. A rectangular link is attached to the bail by means of a small strap for the purpose

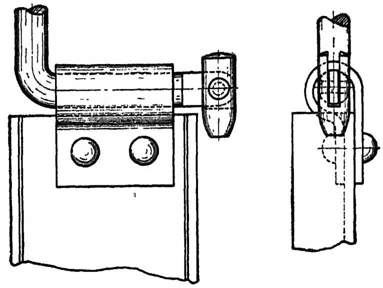


FIG. 83.—Simple self-locking device with bail of round iron bent over on each end.

of placing and removing the bail. The rectangular link is also used for locking the bail into position, and fits over the sliding hook, which is held in place by the socket. To remove the bail it is only necessary to slide the hook up and lift it out of the socket by the link. The bail is very strong and rigid, and since it is of flat shape a good deal of space is saved and the capacity of the car increased. The link is also a decided improvement, and enables the workmen to lift the bail out quickly.

These locking devices have almost entirely replaced the chain which was used formerly. At some works, however, neither bails or chains are used, and the ties or sleepers, or other wood is secured to the car by a wire wound several times round the load."

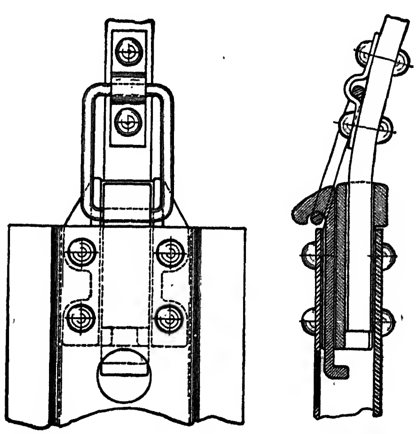


FIG. 84.—Patented device for securing the bail to the arms.

BUMPERS OR BUFFERS.

A great many cars have, according to Mr. Grow, been fitted with bumpers or buffers. Small castings or rein-

forcing straps are attached to the end of the frame sills, or in the more recent patterns a heavy steel casting is attached below the frame.

Coupling Links and Hooks.

At some plants a coupling link is used to fasten the loaded cars together for moving them about in the yard and pushing in and out of the cylinder. An objection to this is the liability to accidents when coupling up the cars. So far, the old scheme of attaching a cable to the load of the last car and the locomotive for pulling the train and pushing the cars by one another has been found very satisfactory.

Some cars have coupling hooks to facilitate handling when empty. In some cases small pulling links are fitted to the side of the car frame, or pins are provided at the end of the car sills, or small brackets are riveted to the arms and frame. Usually the cable hook is attached to a convenient part of the car frame, and the empty cars are pulled around the yard.

Examples of Complete Charging Tram Cars.

No special reference has been made by Mr. Grow to the construction of piling cars under the preceding headings. The construction of tie or sleeper cars, however, can, he says, be applied in a general way to the piling cars. The wheels and axles are the same, with the exception that the axle is heavier to carry the increased load. The frame can be made channel, " T " beam, hood on Z-bar section. Figs. 85 and 86 show two different styles, and it will be noted that the frame is bent down in the middle to make room for the turning bolster. This arrangement increases the capacity of the car to a great extent. The two sills

of the frame are connected in the middle by cross bra
to which the turntable is attached. A heavy king
secures the bolster arm to the turntable and frame.
bolster arms are either made of angle iron, channel
or hood sections. On the old type of car the bol
was made by riveting two angles back to back. The l
cars were made with bolster arm of 12-in. channel,

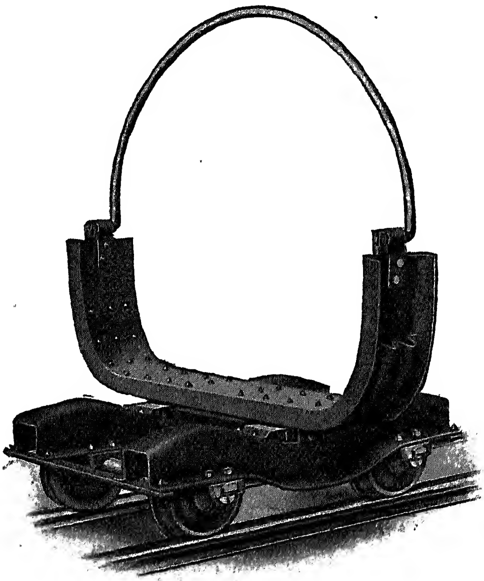


Fig. 85.—Channel arm piling car. Perspective view

inforced with pressed steel braces, as shown by fig
or with a smaller channel.

Piling cars have also been made with the entire f
and bolster of cast steel. In this case the two side
of the frame are made of hood or box section anc
connected by the cast turntable forming a brace.
bolster is made of a casting of tapering channel se

with an additional rib in the middle. Fig. 86 shows a pressed steel construction, and this is the heaviest style of piling car which has ever been built in the U.S. It will be noted that the frame is made of heavy Z-bars braced at each end with heavy plates, and cast steel bumpers. The turntable is secured by means of pressed

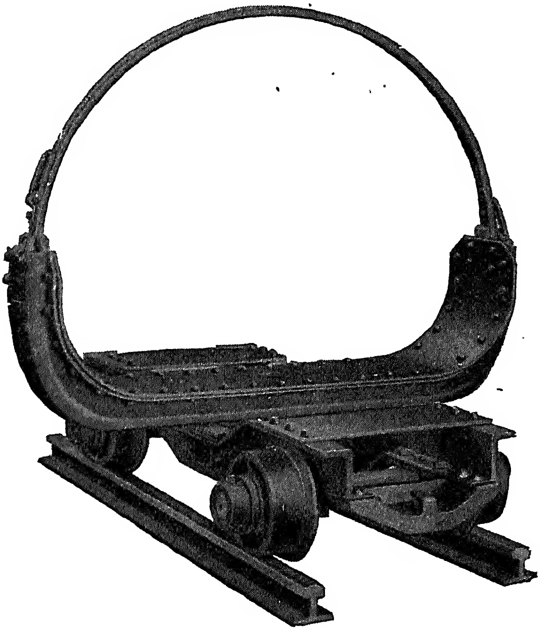


Fig. 86.—Extra heavy piling car. Perspective view.

steel braces connecting the sills of the frame at the middle. The bolster is 12 in. wide, and is made in the shape of a box-section with heavy cover plate. It has a tapering shape with maximum depth where it is bent. The bail is of the flat type with lifting links and locking hooks as shown in detail by fig. 84. The wheels are exceptionally

heavy, and are fitted with spiral roller bearings, the details of construction being shown in fig. 79. The entire car is heavy and rigid throughout, and has been designed with a view to stand up under the heavy strains to which such cars are subjected..

Fig. 87 shows a tie car for a 6 ft. 2 in. diameter cylinder which was designed to obtain a rigid frame with strong

FIG. 87.—Channel arm tie or sleeper car. Perspective view.

arms at a low cost. Frame and bail details are shown by figs. 66 and 86. The frame is very rigid, but the arms, although reinforced with two angles, were found not to be strong enough. This emphasizes the fact that a strong and rigid car designed to meet the severe operating conditions cannot be obtained at a low cost, and if it requires more material in the construction of the car the cost is increased correspondingly.

This fact has been realized, and it will be found by looking over the twelve different car body designs, shown by figs. 60 to 71, that it has been the object of the various designers to construct a car to meet the operating conditions. Not all of the efforts have been successful, and several of the channel and angle arm cars have given out to a certain extent. The arms of the car give the principal difficulty; they either bend out and must be

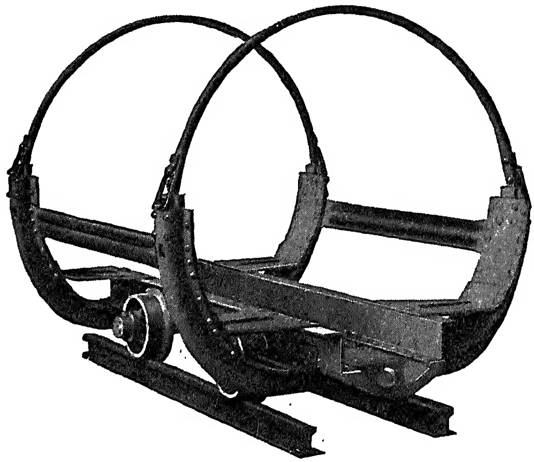


FIG. 88.—Extra heavy tie or sleeper car. Perspective view.

pulled in occasionally, or they bend over in a longitudinal direction. The longitudinal bending usually occurs where the arms curve up from the frame. There is only one way to overcome this difficulty, and that is to construct an arm with sufficient depth, width, and material, which will withstand any bending and twisting strain, either in an outward or sidewise direction. Fig. 88 shows a car of construction which has accomplished this object.

The arms are of such strength that it has been impossible to bend them in any direction.

In addition to the heavy construction of the arms, details of which are shown by fig. 86, they are braced against the Z-bar frame by heavy corrugated plates and against one another by a stout brace connecting the arms at the top. The Z-bar frame is of ample and proper proportions to sustain the heavy load. The cast steel bumper takes up the shock when the cars are knocked together and prevents the striking of the frames against each other. The book on the bumper can be used, if necessary, to couple the empty cars together or move them around the yard. Special attention has been given to the design of car wheels, roller bearings and axles. The wheels (fig. 79) are heavy and have a wide tread; they can be quickly removed to replace wearing washers without disturbing the entire frame. The spiral roller bearing is self-contained and can be removed in one piece for inspection by taking the cap off on the end of the axle.

The bails are arranged for quick and convenient handling. The entire construction of the car is heavy and rigid, and a good deal of experience, thoughtful design and ample material has been incorporated in its manufacture. The car has been in actual operation for a year and has stood up under the hard working strain, and on this account has been very successful.

It will, of course, be realized that a car of this construction cannot be cheap, and that the cost of same must be in proportion to the quality. It is undoubtedly false economy to consider only the first cost of the tram car and lose sight of the fact that if a light car of low cost is bought it will give endless trouble and increase the operating expense which in the long run will make a cheap car

more costly than an expensive one, on account of repairs and its short life.

Prices of Charging Tram Cars.

At the present time cars can be bought, according to Mr. Grow, in the market varying in price from fifty to one hundred dollars, and some of the heavy piling cars are even higher in price. The fact that the better grade of cars are now bought shows that operating men give serious consideration to the car construction and indicates a strong tendency to eliminate the difficulties and troubles caused by the lighter and cheaper cars.

Good heavy and rigid tram cars, while more expensive in first cost, will no doubt give much better results, will ultimately reduce the cost of handling, and will increase the efficiency of the plant.

To maintain a sufficient number of cars involves, says Mr. Grow, a considerable outlay in first cost, and this statement applies especially to large plants, and even in such cases experience has shown that it pays to have an ample equipment of cars. It is now realized that a light and cheap car is really not cheap in the long run, and that it pays to buy heavy and more expensive cars. The old cheap type of car consisting of a channel frame with a few braces and two arms made of bar-iron was under continuous repair, and the blacksmith was kept busy straightening out the arms so that the car could enter the cylinder without causing trouble and delay.

Loading and Unloading Charging Tram Cars.

Fig. 89 is a view showing tie cars at the loading platform, fig. 90 is a view showing a cylinder charge of ties or sleepers ready for treatment, figs. 91 and 92 show

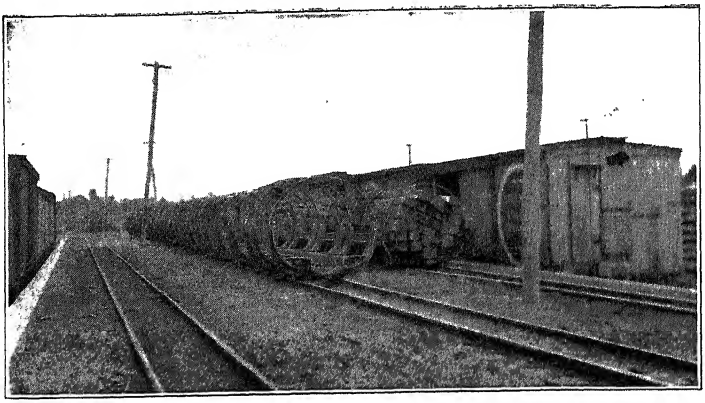


FIG. 89.—View showing cars at loading platform. Perspective view.

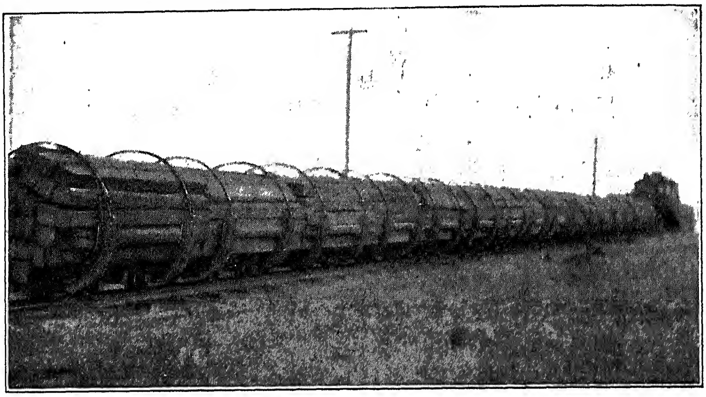


FIG. 90.—View showing one cylinder charge of ties ready for treatment. Perspective view.

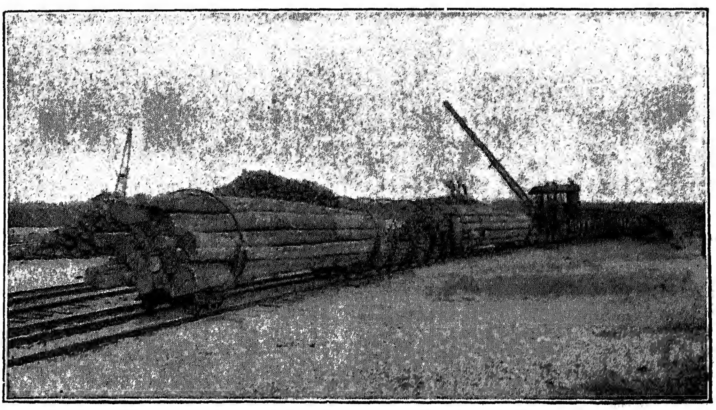


FIG. 91.—View showing arrangement of load on piling cars. Perspective view.

the arrangement of loads on piling cars, and fig. 93 shows the method usually employed for unloading tie cars. The load on the car shown in fig. 93 is approximately 10,000 lb., or about six times the weight of the car. In moving the loaded cars about the yard (figs. 90 and 91) they are subjected to heavy strain by the push of the entire load and by the bumping against one another. When loading cars by hand the ties are dropped into them and at times not any too carefully, and even the empty cars are strained considerably at treating plants where an elevated platform is used, by allowing them to run down the incline by gravity and striking one another as they reach the bottom, the cars frequently jumping the track and being knocked over by the impact. These operating conditions apply also to the cars for piling; in fact, the loads are still more severe, since two cars can only be used for one load of piling. This will be seen from figs. 91 and 92, which shows that the loads carried by the piling car arms are tremendous. The

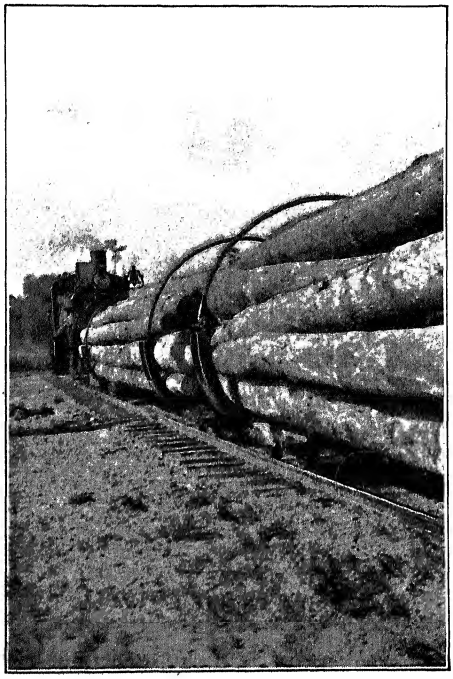


FIG. 92.—View showing arrangement of load on piling cars, Perspective view.

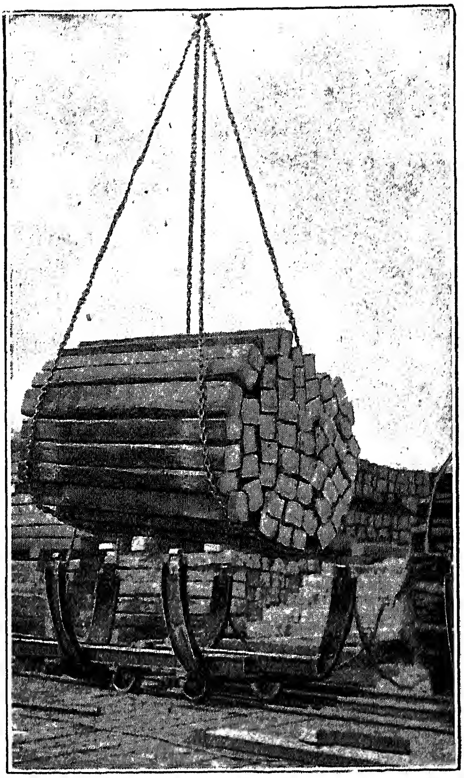


FIG. 93.—View showing method of unloading tie cars. Perspective view.

total weight of one load of piling for two cars is approximately 40,000 lb. or 20,000 lb., of weight on one bolster.

HYDRAULIC *v.* AIR PUMPS FOR FORCING PRESERVATIVES INTO RETORT.

Hydraulic pumps are usually employed for forcing the preservatives into the wood, and this method is found to be both practical and efficient for the purpose. Another method of performing the operation which is also used, though to a lesser extent, is by means of air pumps and compressed air. Compressed air was first used at the works of the C. & N.W.R.R. at Escanaba, Mich. The advantages of air pumps as compared with hydraulic pumps for the above service are discussed by F. J. Angier, Superintendent Timber Preservation, B. & O.R.R., in a paper read at the meeting previously referred to. The timber-treating works of the B. & O.R.R.

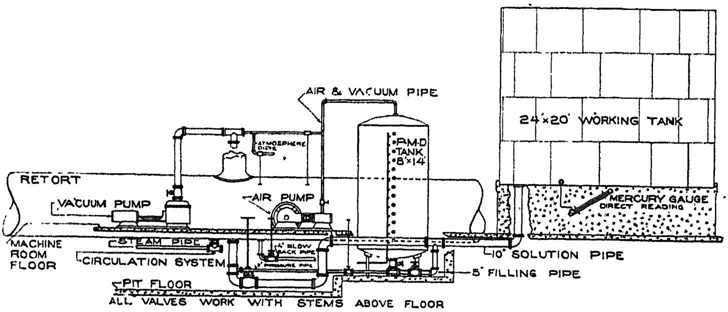


FIG. 94.—Diagram showing arrangement of air pumps for injecting preservatives into wood.

at Green Spring, W. Va., at which it was decided to use the compressed-air system, is taken as an example, and the relative positions of the retorts, tanks, and pumps are shown in the diagrammatical view, fig. 94, from which a general idea of the mode of operation will be gained. Figs. 95 and 96 show some details of construction.

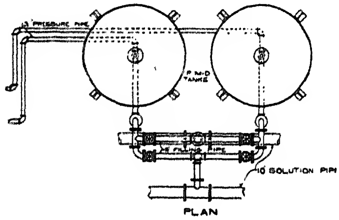


FIG. 95.—Arrangement of air pumps for injecting preservatives into wood. Plan.

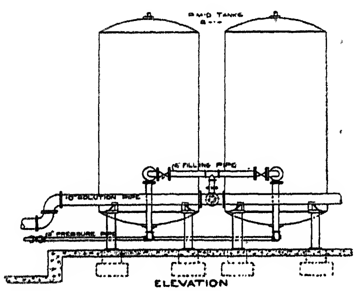


FIG. 96.—Arrangement of air pumps for injecting preservatives into wood. Elevation.

The operation of the apparatus is described by Mr. Angier as follows: "The charge is placed in the retort and the door closed. If material to be treated is green, it is seasoned artificially by steaming. If dry, this

steaming is omitted. In either case an initial vacuum is created, which usually lasts an hour, but the duration of this vacuum depends largely on the amount of steaming or non-steaming. During the vacuum the pressure-measuring-drain (P.M.D.) tank is charged with the preservative solution. It requires about seven minutes to do this, but it can be done while the vacuum is on the retort, thus no time is wasted. At the end of the vacuum, and just before destroying it, the preservative solution is introduced into the retort from the working tank. This flows by gravity through a 10 in. pipe, and requires about thirty minutes to completely fill the retort. Up to this stage of the operation the retort is completely filled with the preservative solution, also the P.M.D. tank contains the requisite amount of solution for treating the charge. This solution has a temperature of 88°C. (190·4°F.) before it is introduced, and is maintained at this temperature, or as near this temperature as possible, during the time of impregnation. Everything is now in readiness for the pressure to be applied. This is accomplished easily and quickly by opening the 3 in. valve in the pipe connecting the bottom of the P.M.D. tank with the retort, forcing the preservatives into the retort and into the wood. When the desired absorption is obtained, as indicated by the gauges on the tank, the air pump is stopped, and the valve in the connecting pipe is closed.

"The next operation is to return the preservative solution in the retort to the working tank. This is done by simply opening the 4 in. blow-back to release the pressure in the retort, then opening the 10 in. valve which leads from the retort to the working tank, and by opening very slightly the 2 in. valve in the pipe leading from the top of the P.M.D. tank to the top of the retort.

Bear in mind, the P.M.D. tank is still charged with air varying in pressure from 125 to 175 lbs., and that this air forces all of the solution remaining in the retort (approximately 21,000 gallons) back into the working tank. To do this requires about twenty minutes, and there is still sufficient air pressure in the tank to force into the working tank what solution might remain in the P.M.D. tank. (At this point the operators of hydraulic pump plants will recognize the advantage of having this air storage, which they are required to pump directly into the retorts with a low-pressure air pump, with more time and expense.)

"Now, a final vacuum is usually required to surface-dry the timber. During this vacuum, which lasts about one hour, about 400 gallons of solution is recovered, or about 10 per cent of the total amount absorbed in the charge. Of course, this regain is due to drip and to the expansion of the atmospheric pressure in the wood during the vacuum. This final vacuum is applied to both the retort and P.M.D. tank. The surplus solution collects in the bottom of the retort and in the pipes leading to the tank, and also seeks its level as it flows by gravity into the tank. At the end of the vacuum period the valve is closed in the pipe leading from the retort to the vacuum pump, and the atmospheric valve opened to the retort, while vacuum is still maintained in the P.M.D. tank. This operation quickly destroys the vacuum in the retort and forces the surplus solution into the P.M.D. tank. The valve in the pipe leading from the retort to the P.M.D. tank is then closed, drainings measured (if desired) and forced back into the working tank by air pressure."

Mr. Angier considers the air pump to possess the following advantages :

"Only one tank is required for each retort, that tank serving in the triple capacity of pressure tank, measuring tank, and drain tank. One air pump is ample for three retorts, while one hydraulic pump is required for each retort. The maintenance of one air pump is much less than three hydraulic pumps, and is decidedly cleaner. The air pump requires less attention, and lessens the cost of packing, lubricants, valves, valve seats, plungers, etc. An air pump is a necessity in plants using hydraulic pumps for blowing back solution, unless those plants are equipped with expensive underground receiving tanks. In the latter case an air pump can be dispensed with in lieu of a large oil pump for pumping solution back into the working tank. The underground receiving tank is more expensive in operation than the air pump, and no doubt this is the reason why so few plants are thus equipped. One air pump can be operated on two or more retorts at the same time without deranging the gauge readings. This is not practicable with hydraulic pumps. Experience has taught us that it is practically impossible to maintain a steady and constant pressure on a charge of timber with a hydraulic pump, even though it is equipped with relief valves, while with the air pump this is easily accomplished. The amount of steam required to operate one air pump is not more than would be required to operate three hydraulic pumps, but as the exhaust steam is used for heating purposes, this feature is not so important. The initial cost of installing the air-pump system is a trifle more than for the hydraulic-pump system, but the maintenance is less, and in the long run air is more economical. With hydraulic pumps there is more machinery to care for, more tanks to look after, and more piping and valves to maintain. There is also

more work for the engineer, and unless everything is compactly arranged the engineer will require an assistant. With the air pump one man can easily look after the entire operation with greater satisfaction and with better results."

The capacities of complete plants built by the Allis-Chalmers Manufacturing Company will be found in the table given on page 149, and also in the table on the folding plate facing page 290. The latter table also gives the weights and approximate cost, and includes amongst other information particulars regarding number of acres of land required for complete plants and yards, storage spaces necessary for lumber, creosote and water, miles of track in yards, and length of loading platforms.

CHAPTER VII

Principal Preservative Agents and Processes.

The Dead Oil of Tar, Bethel or Creosoting Process—The Rueping Process—The Lowry Process—The Curtis Isaacs Process—Processes wherein Creosote is used in Conjunction with some other Agent: The Zinc-creosote, Rutger or Card Process—The Allardyce Process.—The Creo-resinate Process.

THE CREOSOTING PROCESS

AS has been already mentioned, John Bethel evolved in 1838 a practical process for the injection of hot creosote oil, or dead oil of tar,[1] into wood to be preserved, the operation being performed in a closed vessel or retort under pressure. This process is now universally known as "creosoting," which, however, is a misnomer, as dead oil of tar or creosote oil actually contains no real creosote.

The substance is said to owe its success as an antiseptic agent to the presence of insoluble non-volatile substances indifferent to the attacks of oxidation or putrefaction under the conditions to which its product is normally

[1] According to Lunge, a well-known authority on tar products, Bethel originally used an oil containing substantial amounts of tar. In the wood-preserving industry the terms "creosote oil" and "creosote" are at present employed to designate oils of widely varying composition and origin, being applied not only to straight distillates from tars containing phenoloids, but likewise to distillates from the tars lacking phenoloids, and to mixtures of all such distillate oils with both crude and refined tars, and a more specific nomenclature is badly wanted.

exposed. Naphthalin ($C_{10}H_8$), which is a hydrocarbon occurring in large quantities in the heavy coal oils (naphthalinc ompounds amount to from 30 to 60 per cent. by weight), is in its pure state a white substance, taking the form of closely-adhering rhomboidal crystals fusing at 79°C. (174·2° F.), vaporizing at 212° to 220°C. (413° to 428°F.), and having a specific gravity of 0·9778 at its boiling point; insoluble in cold water, slightly soluble in hot water, and slightly volatile at normal temperatures.

A committee of the American Wood Preservers' Association (Proceedings, 1915), gives the following definition of tar and creosote oil: Tar in the scientific sense may be properly defined as the non-aqueous liquid product obtained in the destructive distillation of complex organic matter. Tars vary greatly in character, both chemical and physical. They may be roughly divided into three classes: (*a*) Tars consisting principally of compounds belonging to the aromatic series and containing well-defined amounts of phenoloids. (*b*) Tars consisting principally of compounds belonging to the aromatic series, but lacking phenoloids. (*c*) Tars consisting principally of compounds belonging to the aliphatic series. Creosote oil, in the scientific sense, may be properly defined as any and all distillate oils boiling between 200°C. and 400°C. (392°F. and 750°F.) which are obtained by distillation from tars consisting principally of compounds belonging to the aromatic series and containing well-defined amounts of phenoloids.

The specifications of the Post Office for the creosote treatment of poles contains, amongst other provisos—(*a*) To leave not less than 25 per cent. nor more than 35 per cent. residue when distilled up to a temperature of 316°C. (600·8°F.) (*b*) To contain not less than 15 per

cent. naphthaline. (*c*) To contain not less than 5 per cent. of phenol and other phenoloids. (*d*) To be completely liquid at 38°C. (100·4°F.). (*e*) Not to contain more than 2 per cent. of matter volatile at 100°C. (212°F.)

The heavy or dead oil of tar used for creosoting, according to Mr. Rowe, should not contain more than 1½ per cent. of water, 5 per cent. of tar, and 5 per cent. of phenol or carbolic acid. It must not flash below 85°C. (185°F.), nor burn below 93°C. (199·4°F.), and must be fluid at 48°C. (118·4°F.). It should begin to distil at 160°C. (320°F.), and should yield between that temperature and 210°C. (410°F.) of all substances less than 29 per cent. by volume. Between 210°C. (410°F.) and 243°C. (469·4°F.) the yield of naphthalin must not be less than 40 per cent., nor more than 60 per cent. by volume. At 2° above its liquefying point it should have a maximum specific gravity of 1·05 and a minimum specific gravity of 1·015.

Excellent results have been secured from the use of creosote conforming to a number of specifications;[1] all such oils, however, have been coal tar oils.

In determining the specific gravity, should the temperature of the oil be below 38°C. (100·4°F.), it should be raised to a temperature of from 45° to 50° C. (113° to 122°F.), and then allowed to cool down to 38°C. (100·4°F.), at which temperature the hydrometer reading should be taken. If above 38°C., it should be cooled down as above mentioned. The hydrometer should be one reading specific gravity direct at an temperature of 38°C.

That the presence of creosote in wood does not prevent the entrance of moisture has been proved, and the exclu-

[1] See also Appendix, pages 293–295 for extracts from some other typical creosote oil specifications.

sion of the latter cannot therefore be claimed for creosoting. The reason why creosoting protects timber from decay must therefore be looked for in the fact that the cell walls are protected, in short that the food supplying the destroying fungus is poisoned by the antiseptic.

The above statement as to the penetration of moisture was proved by a test carried out in 1903–1904. Certain (20) telegraph poles were weighed wet out of water, again when dry, and a third time after creosoting; afterwards they were weighed at intervals. The results of the weighings are given in the following table.[1]

		Cwt.	Qrs.	Lb.	Weight per cubic foot in lb.
Oct. 15, 1903	Weight after creosoting	142	1	20	61·82
Apr. 18, 1904	Weight after six months' storing in the open	150	3	25	65·54
July 26, 1904	Weight after nine months' storing in the open, but covered when raining during last three months	141	1	1	61·32
Oct. 18, 1904	Weight after storing in open since July 26	145	3	1	63·27

The 20 poles contained =7·11·6 cubic feet calliper measure, and the oil injected=15·87 lb. per cubic foot.

The "creosoting" process undoubtedly gives excellent results, and is extensively used in this country and in America. Although the first commercially practical

[1] *Creosoted Wooden Poles for Electrical Power Transmission, Telegraph, Telephone Work, etc.: Their Strength and Use.* Richard Wade, Sons & Co., Ltd., Hull.

plant appears to be due to Bethel, an authentic record of the use of creosote oil, for impregnating timber, as far back as 1756 is said to exist. Bethel's experiments showed that by impregnating the wood with a minimum of 7 lb. of creosote per cubic foot satisfactory results were obtained in the case of railway sleepers; for marine work he considered that not less than 10 lb. per cubic foot was required. Other experimenters have employed from 10 lb. to 20 lb. per cubic foot. This question will, however, be found gone into more fully in another chapter.

A standard method of carrying out the "Bethel" or creosoting process is as follows: the wood for treatment, having been carefully dried, is steamed and subjected in a retort to the action of a heated vacuum of from 22 to 24 ins., so that the thorough and uniform penetration of the preserving liquid or agent, essential to the highest efficiency, may be ensured.

The creosote oil or dead oil of tar is then admitted to the chamber, which latter is still maintained connected with the vacuum pump, at a temperature slightly above that of the boiling point of the sap at the pressure in the retort at the time. The oil in the working tank should not be at a temperature below 66°C. (150·8°F.), nor above 88°C. (190·4°F.) when delivered into the impregnating cylinder or retort. During the time that the hot oil is surrounding the wood, and penetrating into the inter-fibrous spaces, any aqueous vapour that still remains in the wood rises to the top of the chamber, owing to its lesser specific gravity, and is drawn off by the pump, and when the chamber is completely filled with oil, all the remaining moisture has passed off.

The exhaust pump is then cut off, and, to facilitate and expedite the impregnation of the wood, a force pump is

started by means of which creosote oil is forced into the chamber or retort until the desired pressure, generally about 125 lb. per square inch, is attained. This pressure is held until the wood has received the required amount of the antiseptic agent. The oil remaining is then withdrawn from the retort and dumped into an underground tank, from whence it is pumped back into the measuring tank, the difference in the reading of the tank gauge before the oil is put into the retort and after it is pumped back into the measuring tank giving approximately the amount of creosote oil injected into the wood. A short final vacuum may be employed to remove surplus oil from the wood.

The impregnation being complete, the retort is opened, the treated wood removed, and another charge can be inserted. The above practice, it will be seen, consists of two distinct operations, the preparation of the wood and the impregnation of the prepared wood with the preservative agent.

The time required to treat any particular wood depends upon the structure, size and shape of the wood, and upon the method of treatment adopted. For operating the full creosote process with 10 lb. treatment the cycle is as follows: steaming to 20 lb. pressure, 30 minutes; steaming to 20 lb. to 35 lb. pressure, 3 hours 30 minutes; blowing off, 15 minutes; vacuum, 45 minutes; creosote oil to a pressure of 100 lb. per square inch, 1 hour 30 minutes; forcing back solution, 15 minutes; vacuum, 15 minutes; total, 7 hours.

The practice in the United States in the case of what is usually termed the "full-cell" creosote process is to employ a pressure of from 100 lbs. to 125 lbs. per square inch, the wood fibres and cells of ties or sleepers being impregnated with from 6 lbs. to 12 lbs. of creosote oil

per cubic foot, and piling with from 10 lbs. to 20 lbs per cubic foot. Sometimes the wood is subjected to a vacuum at the finish to drain the surplus oil from the exterior of the wood, and thus to prevent loss by drippage after the wood has been removed from the retort. The time occupied in this treatment, omitting steaming, is 3 hours, including steaming, 5 to 7 hours, for sleepers; for timber, including steaming, the time occupied by the treatment is 7 to 11 hours, and for piling, 12 to 24 hours.

For wood-paving blocks it was at one time the general practice to inject 20 lb. or even 24 lb. of oil per cubic foot, resulting in excessive bleeding of the oil from the blocks. The practice now is to subject the blocks to a dry heat of from 121° to 138°C. (249·8° to 280·4°F.), or to steam them at pressures varying from 25 lb. to 50 lb. per square inch for periods varying from three to four hours, or more, depending upon the condition of the wood. A vacuum of 24 to 26 inches is then drawn to remove moisture, the preservative being then admitted without breaking the vacuum and the necessary pressure applied. The amount injected is about 16 lb. per cubic foot on the average, according to present practice.

The oil most generally employed has a specific gravity of 1·10 to 1·14, and contains a large proportion of tar, being usually required to be nearly free from carbon. No positive data regarding the value of creosote oil from water gas tar being available, it is at present, as a rule, excluded from specifications.

It is usual in a number of works to add a certain percentage of refined low-carbon coal-tar to creosote oil of a certain grade, that is to say, creosote oil having a specific gravity of approximately 1·03 or less at 38°C. (100·4° F). This addition is made because it was found that by adding a small percentage of coal-tar to creo-

sote of this grade, it is possible to make a heavier grade oil.

A good deal of difference of opinion[1] has been held as to the propriety of this practice, and in view of its growth during recent years a paper by Dr. Hermann von Schrenk and Alfred L. Kammerer was read at the A.R.E.A. Convention in Chicago, March, 1914, outlining the best information available with respect to this subject at the present time. The authors deal with the subject at considerable length, and the paper is very fully illustrated. Amongst the conclusions which they arrive at is that the information available seems to indicate that the addition of low-carbon coal-tar to oils inferior to American Railway Engineering Association No. 1 specification oil does not reduce the penetration obtainable, provided suitable methods are adopted at the creosoting plants to bring about the proper mixture and injection. They find also that little risk is taken from the antiseptic standpoint. The results also seem to indicate that the addition of the refined coal-tar materially tends to retain creosote oil in the timber. The addition also makes possible the

[1] Mr. P. C. Reilly ("Discussion on a Specification for a Coal-tar Creosote Solution," *Proc. American Wood Preservers' Association*, 1915) says that he has found that the degree of penetration of creosote oil is reduced by the addition of coal-tar, and the larger the addition of the tar to the creosote oil the greater the decrease of the penetration of the "solution." This, he says, is a natural consequence, resulting from the addition of a material (tar) having a very high viscosity and low co-efficient of penetration. In fact, the so-called "solution" (tar added to creosote oil) is not altogether a solution, but in part a mixture, and that part of the material which is not entirely dissolved is separated from the solution by the straining nature of the wood fibre, which acts as a filter cloth when wood is treated with the "solution," and there is deposited on the surface of the wood a heavy viscous pitch. This dense, pitchy coating is the element which hinders the free and even penetration of the solution.

utilization of the poorer grades of creosote oil, which are coming more and more into use, and that where such oils are used with the coal-tar addition, smaller quantities can be used at a probably lower cost than where larger quantities of the same inferior oils are used. Remembering these indications, it is pointed out that the coal-tar addition, when properly used, is worthy of trial. Where it is thought desirable to add refined coal-tar to creosote oil, it should be observed that only a low-carbon coal-tar should be used, that is, one having a percentage not to exceed 5 or 6 per cent of free carbon.

Before the combination of creosote and coal-tar is used for the impregnation of timber, the two substances should be thoroughly mixed in a tank reserved for that purpose, preferably at a temperature of about 82°C. (about 180°F.), and during the process of impregnation the temperature of the mixture in the cylinder should be maintained at least at 82°C. If coal-tar, moreover, is used anywhere, it should be mixed with the creosote oil under the immediate direction of the railroad company, or other user, and with their full knowledge.

As a result of a number of tests to determine the distilling points, specific gravities and viscosities of various mixtures, the following specification is given (American Wood Preservers' Association, 1915) for a coal-tar creosote solution: The oil shall be a pure coal-tar product, consisting only of coal-tar distillates and oils obtained by the filtration of coal-tar. It shall contain no admixture of crude tar. Water shall not exceed 2 per cent. Specific gravity at 38°C. (100·4°F.) shall not be less than 1·06 or more than 1·10. Matter insoluble on hot extraction with benzol shall not exceed 2 per cent. Viscosity (Engler) at 82·3°C. (180°F.) shall not be more than 59 for 200 c.c. No variations above 59 seconds shall be

allowed. On distillation by the standard method of the A.R.E.A., it shall yield the following fractions based on dry oil: Not more than 1 per cent. at 170°C. (338°F.); not more than 5 per cent. at 210°C. (410°F.); not more than 30 per cent. at 235°C. (455°F.). The residue at 355°C. (671°F.) shall not exceed 26 per cent.

Fig. 97 is from a photograph of a section through a Baltic pine creosoted sleeper after sixteen years' service. Fig. 98 is a long-leaf creosoted wood paving-block after

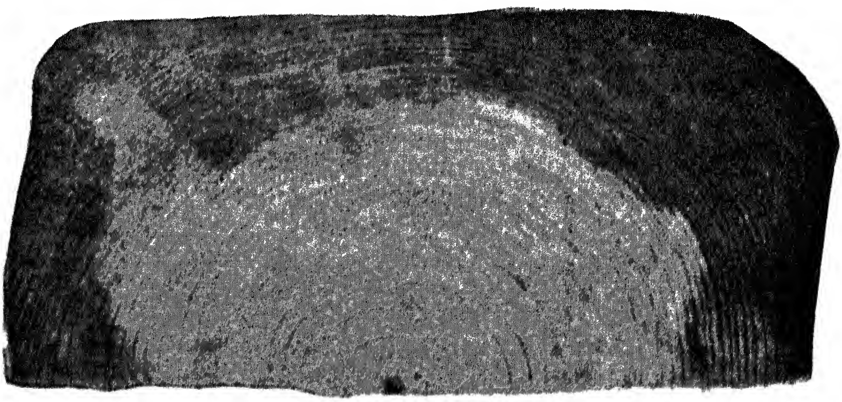


FIG. 97.—Section through a Baltic pine creosoted sleeper after sixteen years' service.

twenty-eight years' service. Fig. 99 is a section of a creosoted pile after twenty-eight years' service. And Fig. 100 is a section of a creosoted pile from Muscogee Wharf at Pensacola, Fla., after it had been in service for more than twenty years. The water at Pensacola has the reputation of being the worst teredo-infested water in the Gulf of Mexico.

It is well known, to those in charge of creosoting works, that it is extremely difficult, if not impossible, to obtain creosote oil completely free from water, and that, even

after nearly anhydrous oil has been obtained, it is very difficult to keep it in that condition. The access of water to the oil takes place from a number of causes, amongst which may be mentioned leaks in the steam coils in the storage tanks; condensation of steam and moisture from the timber in the retort; when underground tanks are used the sepage of ground water through faulty seams or pinholes; and when open tanks are used rain-water will also lodge on the top of the oil. This latter, however,

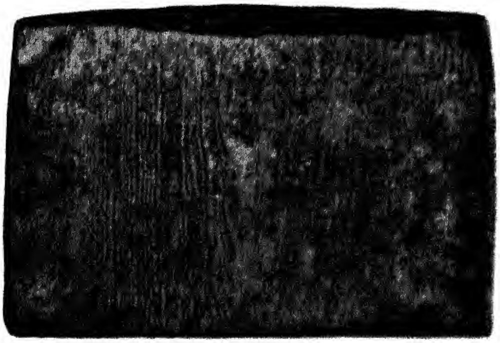


FIG. 98.—Long-leaf creosoted wood paving-block after twenty-eight years' service.

is advantageous inasmuch as it forms a protection against fire and lightning, and practically the whole of it can be syphoned off.

The water can be easily got rid of when the tank is fitted with steam coils and in daily use, but where the oil is stored in a reserve storage tank only drawn on at long intervals, some difficulty will be experienced as in a cold condition there will be a stratification of the contents into three distinct horizontal zones of varying depths depending upon the specific gravity of the oil, viz.: an upper zone consisting of free water; a middle

zone which will be an emulsion; and the lowest zone containing the smallest amount of water in so-called chemical combination with the oil. This latter is usually a small percentage and may be ignored; it is also the most accessible and that generally first used. The water from the emulsion in the middle zone is the most difficult to deal with.

FIG. 99.—Section through a creosoted pile after twenty-eight years' service.

These difficulties are dealt with by Mr. Thomas White, Assistant Manager of American Creosote Works, in a paper read at the 1914 meeting of the American Wood Preservers' Association. Heating the contents to boiling point, he says, in an open tank with steam coils will create an upward circulation, which will continue after the steam has been shut off and until the liquid thoroughly cools. Since the water is lightest it will rise to the top, where it can be readily drawn off. If the tank is provided

with an agitator, it will greatly facilitate the operation, causing quicker evaporation and stratification.

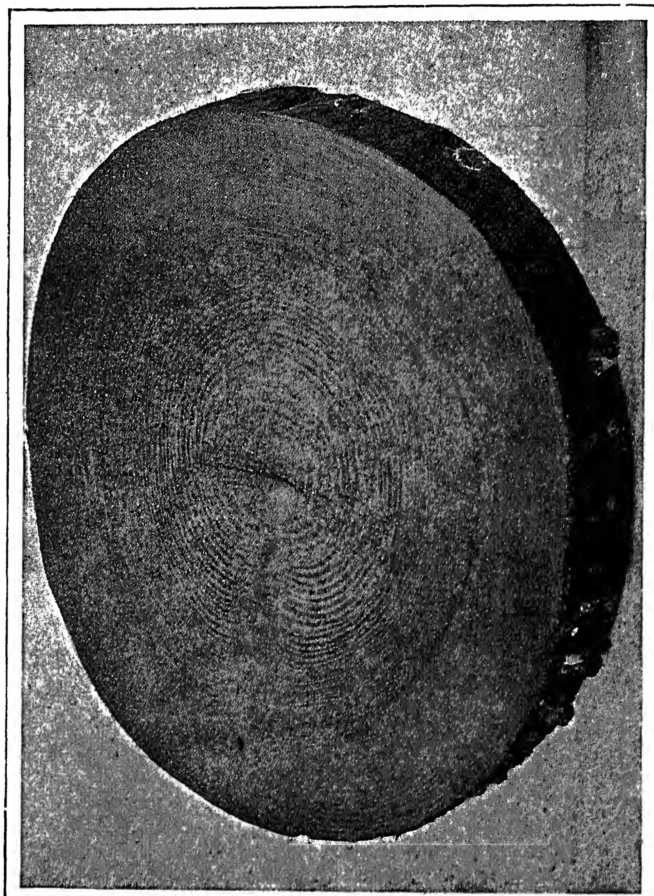


FIG. 100.—Section through a creosoted pile from Muscogee Wharf, Pensacola, Florida, after more than twenty years' service in bad teredo water.

Another method of water extraction, which is the best but not always justifiable at the creosoting plant, is the

still method. Ordinarily, the use of the still for this purpose at the treating plant is seldom required, and in any case its comparatively higher cost of installation and maintenance makes it rather prohibitive. Although the still may be used to refractionate the oil to make either a lighter or heavier one, at the same time the open tank, with its necessary steam coils, is always reserve storage capacity.

Of the two styles of stills, namely, the horizontal and the vertical, Mr. White thinks the latter one most preferable for water removal, although the horizontal still seems to be used almost universally throughout the United States for tar distillation. Even from the point of construction and maintenance, the vertical one is most favourable in that it would not require a separately-built smoke-stack and when burned out at the bottom could be replaced easily. It should induce better evaporation in that there would be a more direct and quicker circulation of the gases. While the heating surface appears less this may be increased by the use of vertical fire flues, which would also serve as smoke-stacks. There would also be less tendency to foam, which means that the operation could be rushed more with less danger of the oil boiling out of the still.

The open-tank method, according to Mr. White, will evaporate at least 1 per cent. of water per day while the liquid is kept heated above 82°C. (179·6°F.), not to mention the free water which would separate and rise to the top. The still method will probably evaporate about 1 per cent. of water per hour. The still would require extra fuel and attention, whereas the open-tank coils would tax the main boiler and its fireman very little more.

Of the numerous other methods of water extraction,

mention may be made of the centrifugal, vacuum, electrical and splash processes.

The centrifugal process is said to operate quite satisfactorily in the case of oils that are free from dirt or suspended matter. Where dirt, however, is present the centrifugal action compacts it in the bowl of the centrifugal machine, in the form of a hard crust, which impedes the action of the machine, and requires the use of cold chisels in order to remove it.

The electrical method consists in the application of high-tension, high-frequency electric currents to the oil in thin layers. To collect the water Dr. Allen uses Canto flannel whilst Mr. Fulweiler employs fine copper gauze.

In the splash method the oil is pumped under pressure against a splash plate, the pressure and size of nozzle being best determined by experiment. Emulsion containing 80 per cent. of water is said to have been reduced to 30 per cent. by this method.

The Committee on Plant Operation, American Wood Preservers' Association, 1915, recommend that the old method of a float gauge be recognized as a standard method for determining the amount of oil injected into a charge of material, the last tank reading shall be converted by correction for temperature into a reading corresponding with the temperature of the first reading, and the difference between the first gauge reading and the corrected last gauge reading will represent the tank feet of fractions thereof injected into the charge, and the weight of oil injected to be determined from this difference as represented in tank feet, taking the weight of oil at 38°C. (100·4°F.) as a basis from which and to which to work, allowing a variation in volume of the oil of 1 per cent. for each 22·5° F. difference in temperature.

Mr. George M. Hunt, chemist, Forest Products Labor-

atory, Madison, Wisconsin, U.S., in a paper read before the same Association, gives particulars of a number of experiments carried out to ascertain the temperature changes in wood under treatment. The material used was sawed maple, red oak, loblolly pine, and hemlock ties 6 in. by 8 in. by $8\frac{1}{2}$ in., as being commercially valuable representatives of ring-porous and diffuse-porous hardwoods, and slightly resinous and highly resinous conifers, both green and seasoned ties being used. The following is a brief abstract giving some description of the apparatus employed, the method of conducting the work, and a summary of the results obtained. The paper is illustrated by a number of diagrams showing the interior temperatures of the specimens during treatment. The treatments were made at the laboratory in a $3\frac{1}{2}$ ft. by 11 ft. treating cylinder equipped with steam coils, thermometers, and pressure and vacuum gauges. Indicating and recording thermometers were used for obtaining the temperature in the cylinder, and a platinum resistance thermometer with a whipple indicator for obtaining the temperature within the tie. A hole $1\frac{1}{4}$ in. diameter was bored into the end of the tie to a depth of over 26 in., an iron bedplate with a hole in the centre being then fastened to the end of the tie, through which the thermometer was passed. In a number of runs the thermometer readings were checked by the use of thermo-electric cartridges. The oven-dry weight per cubic foot was first determined for each tie from a 2-inch moisture disc cut from one end of the tie. This, with the volume of the tie, and its weight at any given time, allowed its moisture content at that time to be calculated. The heating media used were saturated steam at atmospheric pressure 100°C. (212°F.), saturated steam at 20 lb. pressure 126°C. (259°F.), and hot creosote at atmospheric pressure,

In all treatments the heating was continued until the rise in temperature within the tie was not more than 1°C. (1·8°F.) in ten minutes, but in most runs the heating was continued considerably beyond this point. At the conclusion of the heating period a vacuum of 26 in. was applied for an hour. The temperature and pressure of the heating medium and of the interior of the tie were read and recorded at 10-minute intervals. The weight of the tie was taken immediately before and after treatment and usually half an hour and 24 hours after treatment. The results of the experiments are summarized as follows: (1) In most of the ties there was no appreciable rise in interior temperature during the first 30 or 40 minutes. (2) The interior of the ties never quite attained the temperature of the heating medium. (3) In the treatments with steam at 20 lb. pressure, the time required for the interior to reach 100°C. (212°F.) varied from 2¾ to 5 hours, the average being 4 hours and 20 minutes. (4) Upon the application of the vacuum the interior temperature fell very rapidly. (5) The rate of increase of interior temperature was greatest in the treatment with steam at 20 lb. pressure, and least with creosote at 85°C. (185°F.). (6) The rate of increase of interior temperature was slightly greater in the treatment with steam at 100°C. (212°F.) than with creosote at the same temperature at zero gauge pressure. (7) Seasoned ties heated more rapidly than green ties. (8) No appreciable difference in the rate of increase of interior temperature due to difference in species could be determined. (9) In the steam and vacuum treatments, green ties always showed a loss of moisture, while seasoned ties sometimes showed a gain and sometimes a loss. (10) Practically all the ties continued to lose weight during the first 24 hours after treatment. Creosoted ties lost less weight during this

EFFECT OF TREATMENT ON MOISTURE CONTENT.
G. M. Hunt. Forest Product Laboratory, U.S.

Species.	Tie No.	Heating Medium.	Moisture Content.* Before Treatment.	Immediately after Treatment.	24 hours after Treatment.
			Per cent.	Per cent.	Per cent.
Red Oak . . .	2	Steam 20 lb. per sq. in.	65	52	50
,, ,, . . .	5		67	58	56
,, ,, . . .	8		69	54	54
Hard Maple . .	11		80	71	63
,, ,, . .	14		66	61	59
,, ,, . .	17		18†	22	15
Loblolly Pine. .	29		46†	41	39
,, ,, . .	32		26†	27	24
,, ,, . .	35		47†	45	43
Eastern Hemlock	23		38†	34	31
,, ,,	26		21†	19	17
Red Oak . . .	1	Steam Atmospheric Pressure	28†	29	27
,, ,, . . .	4		99	89	88
,, ,, . . .	7		89	87	83
Hard Maple . .	10		52	49	45
,, ,, . .	13		95	89	84
,, ,, . .	16		45	44	41
Loblolly Pine .	28		29†	23	19
,, ,, .	31		34†	30	27
,, ,, .	34		39†	42	37
Eastern Hemlock	22		38†	38	25
,, ,,	25		27†	27	25
Red Oak . . .	6	Creosote	60	?‡	?‡
,, ,, . . .	9		72	,,	,,
Hard Maple . .	15		70	,,	,,
,, ,, . .	18		79	,,	,,
Loblolly Pine . .	33†		44	,,	,,
,, ,, . .	36†		15	,,	,,
Red Oak . . .	3		65	,,	,,
Hard Maple . .	12		49	,,	,,
Loblolly Pine .	30†		31	,,	,,

* Based on oven-dry weight of wood. † Seasoned tie.
‡ Moisture content unknown, due to absorption of undetermined quantity of creosote.

period than steamed ties. (11) In the treatment with steam at 20 lb. pressure, the green ties were badly checked, while seasoned ties were not so seriously affected. In the other treatments none of the ties were seriously checked.

The Boulton-Curtis-Isaacs-Buehler Process.

This method, which is known as the Boulton process (Pat. 1879 Curtis & Isaacs, Pat. 1895 Buehler), is said to be in extensive use on the Pacific Coast for the treatment of Douglas fir. Briefly, the process is carried out as follows: The wood to be treated either in a green or partially seasoned condition is run into a cylinder or retort on tram-cars and the door secured. The charge of antiseptic—generally creosote oil—is admitted until the wood is submerged and the temperature is raised to 101·6°C. to 107·2°C. (215°F. to 225°F.) and boiling kept up for from 4 to 8 hours according to the character of the wood and the condition in which it is when being treated. The process sometimes includes the application of a vacuum to assist in the liberation of the saps from the wood. Pressure is next applied and maintained until the desired absorption has been obtained, or until such time as the wood refuses to take in any more fluid. The pressure is then stopped, the surplus fluid is drained from the retort, after which a vacuum is formed for the purpose of expediting the drying of the wood and to prevent dripping when removed. The antiseptic or preservative extracted from the treated wood by the vacuum is drained from the retort and run back into the working tank.

The Rueping or Rüping Process.

Briefly, this process, which is chiefly used with oil of creosote as an agent, consists in forcing compressed air at a pressure of from 80 lb. to 100 lb. per square inch into

the pores or cells of the wood (previously either air-seasoned or steamed in a retort), and, at a higher pressure, creosote oil, without relieving the air pressure.

The retort is filled with oil by means of an equalizing reservoir or pump, so as to avoid releasing the air pressure. The oil pressure thus started at from 80 lb. to 100 lb. per square inch is then gradually increased to about 150 lb. per square inch, compressing the air that has been forced into the cells or pores of the wood into a smaller volume, and allowing from about 10 lb. to 12 lb. of creosote oil per cubic foot to enter the wood.

Upon relieving the combined air and oil pressure, and draining the oil from the retort, a vacuum, or rather a partial vacuum, is produced therein, which permits the air enclosed in the cells or pores of the wood to expand and force out the surplus oil from the wood fibres, leaving the latter impregnated, according to some authorities, with from 4 lb. to 6 lb. of creosote per cubic foot, and, according to others, with as little as 2·2 lb. per cubic foot.

This process is on what is known as the empty cell treatment, and aims to materially reduce the final amount of creosote retained per cubic foot, whilst at the same time giving an equal depth of penetration, and it is claimed to be especially adapted for the treatment of ties or sleepers. The time occupied in treating sleepers, omitting steaming, is about 4½ hours, or, including steaming, 6½ to 8½ hours. The time occupied in carrying out the different stages of the process, using equalizing cylinders, is as follows: air to 80 lb. pressure per square inch, 30 minutes; transferring creosote oil, 20 minutes; creosote oil to 150 lb. pressure per square inch, 1 hour 30 minutes; maintaining 150 lb. pressure per square inch, 15 minutes; forcing back creosote oil, 20 minutes; vacuum, 1 hour; maintaining vacuum, 15 minutes; drain-

ing, 10 minutes; total time occupied, 4 hours 20 minutes.

The Rueping process has been patented in Great Britain, Germany, and the United States. It was primarily devised with the object of reducing the cost of creosoting by preventing the heavy loss occasioned by dripping when the wood is treated by the ordinary process.

Large quantities of oil are known to drain out of wood creosoted in the ordinary way when placed in vertical positions in the ground, such as telegraph poles and posts, and to a somewhat lesser extent from such wood when placed horizontally.[1] The following table gives the result of a test made by Messrs. Richard Wade, Sons & Co., Ltd., to ascertain what amount of creosote is really lost in this way. The test was commenced in the winter months, when creosote is less liquid than during the summer months:

No.	L.	Diameter, middle.	Cubical contents. Calliper measure.	Weight before creosoting. Oct. 13, 1910.	Weight after creosoting. Oct. 13, 1910.	Absorption of creosote per cubic foot.	Subsequent Weighings. Nov. 1, 1910.	Jan. 21, 1911.	May 11, 1911.	July 10, 1911.	Loss of creosote per cubic foot.
		in.		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1	24	6½	5·53	258	318	10·85	312	290	280	278	7·23
2	,,	7¼	6·88	292	402	15·98	397	379	356	241	8·87
3	,,	,,	,,	248	344	13·98	340	318	302	293	7·41
4	,,	,,	,,	268	398	18·89	393	371	360	334	9·30

Note: The above poles were laid on the ground horizontally for three weeks, to allow the creosote to solidify as much as possible before erecting on end.

[1] See also "Bleeding and Swelling of Paving Blocks," Appendix, pages 307–309.

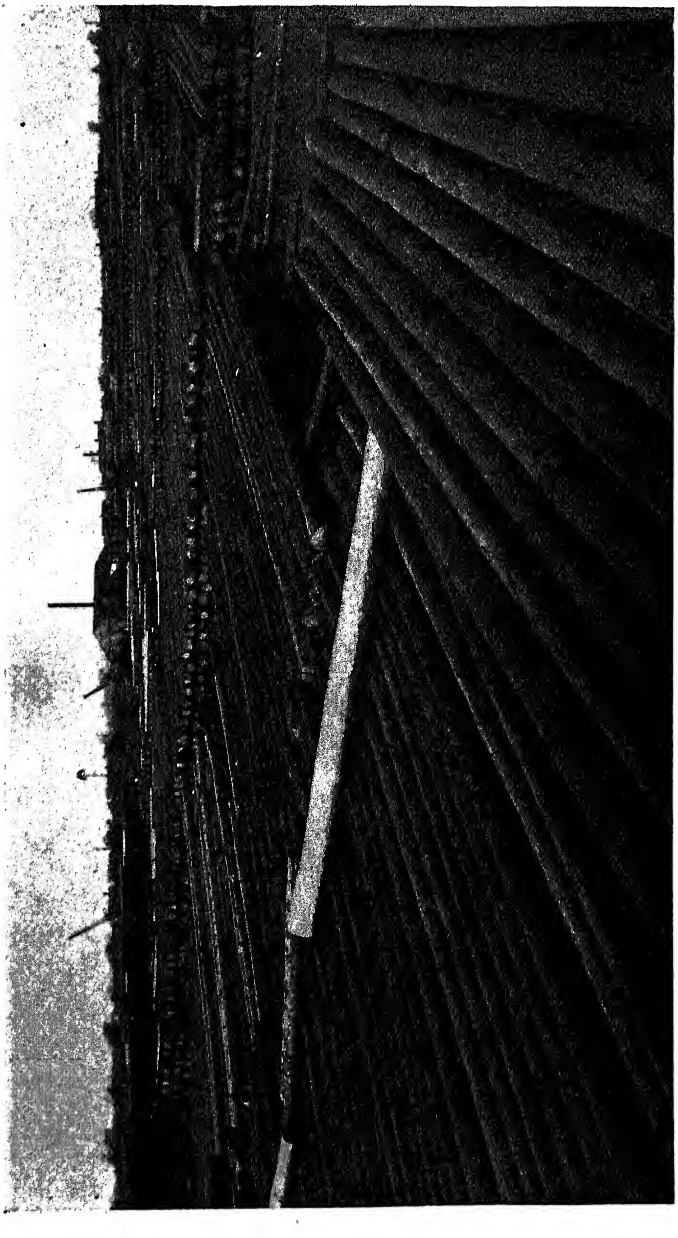


FIG. 101.—Messrs. R. Wade, Sons & Co.'s Ruepenizing Works, Staddlethorpe, Yorks. View showing pole yard with impregnating works in the distance.

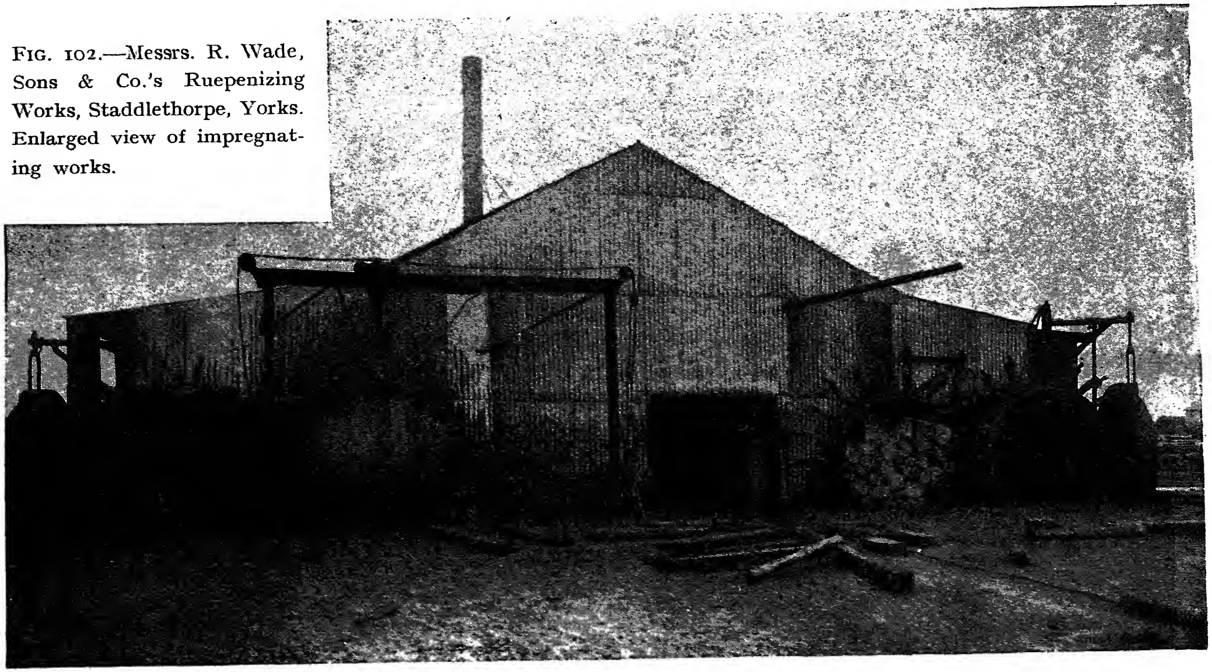


FIG. 102.—Messrs. R. Wade, Sons & Co.'s Ruepenizing Works, Staddlethorpe, Yorks. Enlarged view of impregnating works.

The creosote used in test gave on analysis the following results :

Specific gravity at 15·5°C. (60°F.)	10·72
Total distillate at 100°C. (212°F.)	0·91
" " " 315·5°C. (600°F.)	74·68

Messrs. Richard Wade, Sons & Co., of Hull ; Burt, Boulton & Haywood, Ltd., ; Armstrong, Addison & Co.,

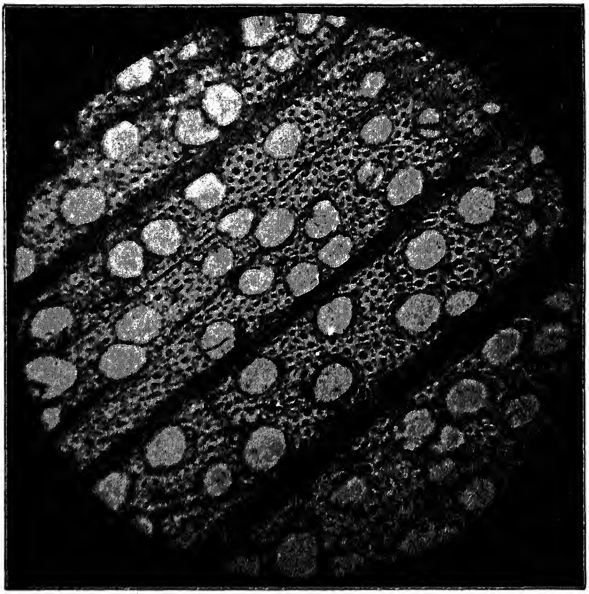


FIG. 103.—Section of beechwood treated by the Rueping process, magnified 100 diameters.

Ltd. ; English Bros., Ltd. ; Corry & Co. ; and The Post and Telegraph Lines are at the present time concessioners for the working of the Rueping process in the United Kingdom. Figs. 101 and 102 are two views of Messrs. Wade's works at Staddlethorpe, Yorkshire. The first

view shows the pole yard with the impregnating works in the distance, and the second an enlarged view of the impregnating works. In this country, the writer understands, the usual practice is to force the compressed air into the wood at a pressure of about 50 lb. per square inch.

The advantages claimed for the Rueping process are: A thorough saturation of the whole of that portion of

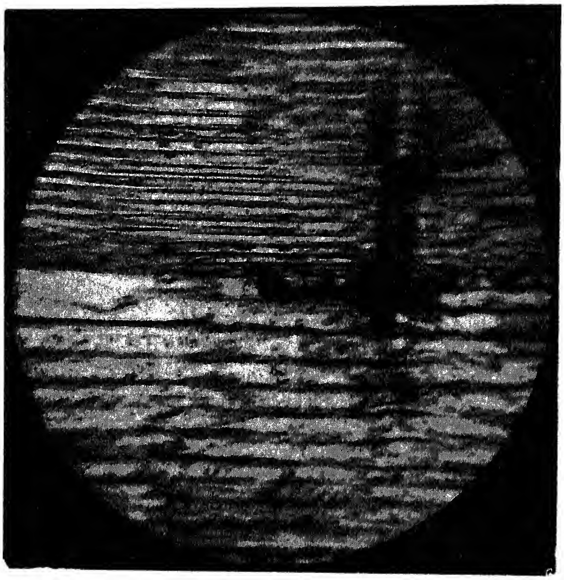


FIG. 104.—Section of red fir treated by the Rueping process, magnified 180 diameters.

the timber which can be saturated by the preserving liquid. The absorption of only so much liquid as is necessary to accomplish this. The oozing and sweating of wood is completely prevented, the timber being dry and clean. A great saving in cost without reducing the life of the timber.

Figs. 103 to 109 show various descriptions of wood

FIG. 105.

FIG. 106.

FIG. 107.

FIG. 108.

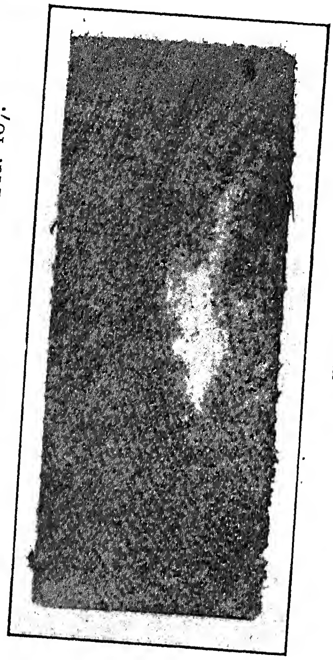


FIG. 109.

FIGS. 105, 106, 107, 108 and 109.—Sections of redwood sleepers treated by the Rueping process with 4 lb. of creosote oil per cubic foot.

treated on the Rueping system, from which it will be seen that a very effective penetration of the antiseptic is secured. Fig. 103 is a section of beech wood magnified 100 diameters. Fig. 104 is a section of a piece of red fir magnified 180 diameters. Figs. 105 to 109 are sections of redwood sleepers also treated by the Rueping process with 4 lb. of creosote oil per cubic foot of timber. The above illustrations, Figs. 103 and 104 of which are by Messrs. Hulsberg & Co., Berlin, have been reproduced from a publication of Messrs. Richard Wade, Sons & Co., Ltd., on "The Antiseptic Treatment of Timber, or The Rüping Process of Creosoting."

The Lowry Process.

In the Lowry process, also operating on the empty cell treatment, the seasoned wood is placed in the retort and submerged in creosote oil, from 10 lb. to 12 lb. of which, per cubic foot of wood, is forced in at a pressure of about 180 lb. per square inch, so as to saturate the pores and cells. The retort is then drained, and a quick vacuum produced and maintained for from one to two hours, leaving the wood fibres finally impregnated with from 4 lb. to 6 lb. of oil per cubic foot.

This process is chiefly intended for the treatment of sleepers, and the time occupied in the impregnation of thoroughly air-seasoned wood is from four to six hours. The details of the process are: creosote oil, 2 hours; draining creosote oil from retort, 10 minutes; vacuum, 2 hours; draining, 10 minutes; total, 4 hours 20 minutes. The average temperature of light creosote oil during the treatment is 77°C. (170°F.), and of heavy creosote oil 82°C. (180°F.).

The Curtis-Isaacs Creosoting Process.

A process for creosoting, patented some years ago in the United States by W. G. Curtis and J. Isaacs, of San Francisco, consists in placing the charge of timber to be treated in a retort having open vents or ports to the atmosphere, introducing sufficient oil of creosote to submerge the charge, and then heating the oil and timber to a temperature above the boiling point of the sap at ordinary atmospheric pressure, by which it is claimed that the sap is expelled from the wood. The ports or vents are then closed and the oil is forced under pressure into the pores of the wood to take the place of the evaporated sap.

The Zinc-creosote or Rutger Process.

According to this process, which appears to have been first introduced in Germany by Julius Rutger in the year 1874, the wood first air-seasoned, or steamed in a retort—preferably both—to reduce moisture and expel the sap, is subjected to a vacuum for one hour. The retort is then filled with a hot emulsion formed of ½ lb. of dry zinc, and from 1·5 lb. to 4 lb. of oil of creosote per cubic foot of timber being treated. Pressure is next applied by forcing in additional emulsion at a pressure of between 100 lb. and 150 lb. per square inch, after which the retort is drained and a vacuum produced and maintained for about half an hour, to draw out the surplus emulsion from the exterior of the wood, and so prevent loss—as in the processes previously described—by dripping after the wood is removed from the retort.

It should be noted that it is necessary either to employ a special oil, or to keep the emulsion in a constant state of agitation during the operation, in order to prevent a

separation of the zinc and the creosote oil. The requisite agitation is usually affected by a centrifugal pump, which draws the emulsion from the top of the retort and discharges it into the bottom, through a perforated pipe.

This process, which is likewise intended principally for the treatment of sleepers, requires for the latter, including steaming, from six to nine hours. The full details of the treatment are: steaming to 20 lb. pressure per square inch, 30 minutes; steaming to 20 lb. to 35 lb. pressure per square inch, 3 hours 30 minutes; blowing off steam, 10 minutes; vacuum, 1 hour; emulsion to 120 lbs. pressure per square inch, 1 hour; maintaining 120 lb. pressure per square inch, 1 hour 30 minutes; forcing back oil, 15 minutes; vacuum, 20 minutes; draining, 10 minutes; total, 8 hours 25 minutes. The steaming time is frequently reduced by 2 hours, in which case the time occupied would be 6 hours 25 minutes.

The Card and the Allardyce Processes.

The zinc-creosote process is sometimes, especially in the United States, known as the Card process, from Mr. J. B. Card, who has introduced several improvements in working.

A zinc-creosote process has also been devised by Allardyce, and both methods have been practised for some years in the United States. The most extensively used treatment is the Card, in which the creosote and the chloride of zinc, which are of different specific gravities, are emulsified by means of a centrifugal pump. The Allardyce process, which is used to a lesser extent, consists in a two-movement application of the two preservative agents.

The Creo-resinate Process.

This process is used by the United States Wood Preserving Company, of New York, and, according to good authority, is a very efficient one for wood paving-blocks. The chief novel feature in the process seems to be the substitution for steam of air raised to a temperature of 121°C. (250°F.), and at a pressure of about 100 lb. to the square inch. The air pressure is claimed to prevent the checking of the block, and the air is kept at the same temperature and pressure until the centre of the wood being treated reaches a temperature of 100°C. (212°F.), at which all germ life, the chief cause of decay, is destroyed. The temperature of the air is then reduced to 65·5°C. (150°F.), and subsequently the air is exhausted from the retort and a vacuum of 26 inches is pumped, the charge of antiseptic agent being then inserted. This agent consists of 50 per cent. of oil of creosote, 48 per cent. of resin, and 2 per cent. of formaldehyde. This mixture is forced into the wood under pressure so that the pores are thoroughly impregnated, and 22 lb. per cubic foot is taken up. The wood is next transferred to another retort and treated with a solution of lime, raised to a temperature of 100°C. (212°F.) and at a pressure of 150 lb. per square inch. The wood is then allowed to cool gradually.

Saponified Creosote.

The idea of using saponified creosote appears to have first occurred to Mr. S. H. Collins, M.Sc., of Armstrong College, Newcastle-upon-Tyne, and is intended chiefly as a means of cheapening the creosoting process by permitting of a reduction in the strength of the liquid by the addition of water. Saponified creosote is thus rendered available

for the treatment of timber, on the simple open-tank method, for estate work, and performs the same office of cheapening the latter as the Rueping process does for the pure creosote method, by enabling a portion of the surplus liquid which has not been actually taken up by the walls, etc., of the wood elements to be withdrawn. Saponified creosote is also asserted to give excellent results as regards penetration.

A paper [1] on the "Preservative Treatment of Timber for Estate Purposes," by J. F. Annand, M.Sc., of the above-mentioned college, gives the results of a number of experiments with saponified creosote by the open-tank method. The woods selected for the experimental treatment were Scots pine, spruce, sycamore, and beech, which are considered typical of the species of timber commonly used for fencing and other estate purposes, and the inferior sorts of which cannot be used with advantage without the help of some preservative. Scots pine is a wood which takes large quantities of creosote, whilst spruce absorbs the oil with difficulty even when comparatively well seasoned.

The creosote oil used was taken from average samples of about 2,000 barrels in use on a Northumberland estate for preserving estate timber, the price of the oil, including carriage, being 4¾*d.* per gallon. The analysis of this creosote made by Mr. Collins gave the following results :

	Per cent.
Light oils (under temperature 205°C., 410°F.)	13·5
*Naphthalene oils (205° to 245°C., 410° to 473°F.)	37·0
Heavy oils (245 to 271°C., 473° to 519·8°F.)	28·7
Pitch (over 316°C., 600·8°F.)	14·3
Middle oils (245° to 271°C., 473° to 519·8°F.)	6·5
	100·0
Water	None

* Containing Naphthalene, 6·0.

[1] *Quarterly Journal of Forestry*, July, 1914.

The saponification of the creosote is obtained by adding a very small proportion ($\frac{1}{4}$ per cent. or less) of sodium hydroxide or caustic soda (NaHO). The saponified creosote can be diluted to any desired extent by the addition of water. In the experiments creosotes saponified by caustic soda and with water added were used of the following strengths: 100 per cent., 50 per cent., $33\frac{1}{3}$ per cent., and 10 per cent.

The paper under consideration contains a large amount of tabulated and other data relating to the experiments in question, the following being the main conclusions arrived at:

The addition of a small percentage ($\frac{1}{4}$ per cent. or less) of caustic soda in pure creosote improves penetration in the case of timbers which take the preservative with difficulty. Saponification of the creosote makes it possible to dilute the preservative by the addition of water, and thus cheapens the creosoting process. Average creosote may be diluted to half its full strength with good results—if much weaker, the penetration becomes less complete, especially in the case of green, or only partially seasoned timber.

CHAPTER VIII

Principal Preservative Agents and Processes (continued)

The Bichloride of Mercury Process or "Kyanizing"—The Zinc-chloride Process or "Burnettizing"—"Burnettizine"—The Zinc-tannin or Wellhouse Process—The Boucherie Process—The Hasselmann Process—The Vulcanizing or Haskinizing Process—The Saccharine Solution or "Powellizing" Process—The Guissani Process—The Cresol-calcium Process—The Aczol Process—The Naphthalene Process—The Use of Natural Oils as Preservative Agents.

The Bichloride of Mercury Process or "Kyanizing."

THE preservative process usually known as "kyanizing," from the name of the inventor, John Howard Kyan, who introduced it into this country in the year 1832, consists in steeping or soaking the wood in a solution of bichloride of mercury or corrosive sublimate ($HgCl_2$), the solution generally used consisting of 1 lb. of the salt to 99 lb. of water.

In the year 1836 this process was introduced in Woolwich by the Royal Engineers, but it has now practically gone out of use in England. The chief objections to the process are the high cost of the agent, and that, being carried out without pressure, it is a comparatively slow one, occupying as many days as the pressure processes do hours. According to Mr. Samuel M. Rowe, an authority on the preservation of timber in America, the usual rule there—where the process is being carried on in some localities, the most notable plants being those of the

Berlin Mills Co., at Berlin, N.H., and Otis Allen & Co., at Lowell, Mass., and Portsmouth, N.H.—is to allow the wood to steep in vats for a length of time depending upon its least thickness, thus if the timber is 10 ins. × 12 ins. thick it would remain in the vats eleven days; if 6 ins. × 9 ins. it would steep for seven days.

The wood is completely freed from bark and after having been air-seasoned is placed in the steeping tank. Cross-ties are placed over the wood and lastly top beams, kept down by iron clamps. The solution is then pumped into the tank, and according to Dr. F. Moll, well-seasoned wood will absorb within a week liquid to the extent of about 10 per cent. of its volume. From time to time fresh solution must be added, and as the quantity of salt absorbed by the wood is relatively larger than the amount of water that is absorbed, the degree of concentration of the solution will fall below the desired one of 1 in 150. When the solution becomes too weak, it should be strengthened by the addition of sublimate, which may be dissolved in a suitable dissolving pan. The most simple method of ascertaining the strength of the solution is, according to Dr. Moll, that by titration in a gauged test-tube by means of a solution of iodide of potassium of known concentration.

After the wood has been in the steeping tank for a sufficient time, the remainder of the solution is drained out through a valve situated at the bottom. The top beams are then removed from the tank and the impregnated wood is taken out and transferred to the stores.

Since 1900 nine works have been established in Germany and Austria for operating on the "Kyanizing" process.

Owing to the bichloride of mercury used as the antiseptic in this process containing hydrochloric or muriatic

acid (HCl), which acts injuriously on iron, it has been found impracticable to attempt to impregnate the wood under pressure.

The labours of Pasteur and Hartig have shown that apparently the effect produced by the sublimate lies in its exceedingly toxic effect upon the living plant cell, that is to say in this case the cell of the wood attacking and destroying fungus.

The Zinc-chloride Process or "Burnettizing"

Sir William Burnett's invention, known as "burnettizing," was introduced in 1838, and the process consists briefly in the destruction of the tendency possessed by certain vegetable and animal substances to decay, by subjecting them to the action of chloride of zinc ($ZnCl_2$). The degree of dilution recommended by the inventor is 1 part by volume to 50 parts of water, and the impregnation is now most commonly carried out under a pressure of 7 or 8 atmospheres, as used in creosoting. In Germany, where the process is probably the most used, the wood is steamed under a pressure of from 60 lbs. to 70 lbs. per square inch, preparatory to burnettizing. The solution employed is generally composed of 2·5 per cent. of zinc-chloride and 97·5 per cent. of water.

In the United States the solution most commonly used consists of ·5 lb. of dry zinc per cubic foot of wood treated. The wood to be treated is first air-seasoned in the open, or steamed in closed retorts to expel moisture. The first stage of the cycle consists in subjecting the wood in the retort to a vacuum, which is maintained until the solution is introduced, and the wood is completely submerged. Additional solution is then pumped in and the pressure increased to about 100 lbs. or 125 lbs. per square inch, until the required amount of penetration and impregnation is

obtained, the remaining solution is then drained from the retort.

Two reports made by committees of experts to the American Wood Preservers' Association in January, 1915, recommend that the above standard practice, which ensures the retention of ½ lb. of dry salt per cubic foot of timber, should be the minimum, and suggest that under usual conditions a ¾ lb. injection per cubic foot would be advisable. The following method of preparing the solution is given: The fused chloride shall be put into a small vat, or tank, preferably of steel construction, and water added until same is converted into a concentrated solution (about a 50 per cent. solution); this is to be added to solution in working tank as needed. The best results are obtained when the solution is maintained at an even strength in all parts of the working tank, and it is essential that proper provision be made for keeping the working solution well mixed.

The solution used consists of a combination of zinc spelter with hydrochloric acid, leaving no free acid. The strength of the solution is perhaps best arrived at by experiments with the particular wood to be treated.

It is important that the zinc-chloride should be as free from all impurities of any kind as is practicable, being basic and devoid of free acid. The commercial chloride is dissolved, shortly before being required for use, into a concentrated stock solution from 35 to 50 per cent. in strength to ensure thorough dissolving, and any free acid being taken up by the spelter placed in the vat. The diluted solution is made by the addition of the requisite amount of water to this stock solution, the most convenient method of testing the strength of the solution being the Beaumé hydrometer.

The full programme of the process is as follows:

Steaming to 20 lb. pressure per square inch for 30 minutes; steaming from 20 lb. to 35 lb. pressure per square inch for 3 hours 30 minutes; blowing off steam, 15 minutes; vacuum, 45 minutes; solution to about 100 lb. pressure per square inch, 45 minutes; solution maintained at 100 lb. pressure per square inch, 1 hour 15 minutes; forcing back solution, 15 minutes; total time, 7 hours 15 minutes; or, if the steaming time be reduced by 2 hours, 5 hours 15 minutes.

The principal recommendation possessed by this agent is that of cheapness. It possesses no value for the protection of piles or timber against the attacks of marine worms, although it is said to be useful as an aid to the impregnation of piles, etc., with creosote.

The use of this process is recommended in arid or semi-arid regions, and particularly on track ties and other material with mechanical life limited to eleven years; also for woods resistant to creosote. It should not be used where mechanical wear is eliminated, nor in situations where the treated timber is in permanent or intermittent contact with either stagnant or flowing water. It is also thought that consideration should be given to its use on overhead trestles and similar structures, and under usual conditions three months' seasoning after treatment is recommended as being advantageous.

When timber impregnated with zinc-chloride is subjected to wet, a certain amount of the agent wastes or leaches out, the percentage of loss gradually diminishing. This loss does not appear, however, on investigation to be so serious a matter as it would seem at first sight. Experiments, described in the *Engineering News*, made by Mr. Octave Chanute with wood treated by the zinc-chloride process, during which efforts were made to extract the preservative by long-continued and oft-

repeated series of immersions in water, showed on drying and analysing that, although a small, regularly-decreasing amount does waste out, after about eighteen months of strenuous treatment, only 28 per cent. of that originally absorbed was extracted.

Another series of leaching tests (F. J. Angier, Proc. Amer. Wood Preservers' Association, 1915) made with Lodgepole pine and Douglas fir ties, some seasoned for six months after treatment and before the test for leaching was begun, and others freshly treated and full of the water solution, gave the following results: Less than 30 per cent. of the zinc chloride was removed from the wood in nearly a year's time, and the largest part was leached out in the first 70 days, or approximately 18 per cent. It was also shown that with freshly treated ties the leaching was much more rapid, almost the entire loss being within 70 days. The test was carried out by weighing the ties before and after treatment, to find as nearly as possible the number of grains of pure zinc chloride absorbed by each tie. Each tie was submerged in a pan filled with water and left for 24 hours, after which it was taken out and allowed to dry for six days, the process being repeated continuously for many months. After each soaking a measured quantity of the water was taken out from the pan and the amount of zinc chloride determined.

The appliances required for carrying out the zinc-chloride process are practically the same as those used for "creosoting," except that for the latter process a storage tank will be required for receiving the oil, and that the retort or impregnating cylinder is fitted with steam-heating pipes to maintain the necessary fluidity of the oil. The main pipes through which the oil is passed should also, for the latter process, be heated by internal steam-pipes for the same purpose.

BURNETTIZINE.

This proprietary preservative solution is made by Sir W. Burnett & Co., Ltd. It is used by the Post Office for telegraph poles where creosoting would be undesirable, also by railway, dock, and shipping companies.

This agent is claimed not only to preserve the wood against decay, but to render it practically fireproof as well as strengthening it, and, moreover, to leave it clean and odourless. It is said to enter the heart of the wood and form an insoluble chemical combination that will not wash out.

The process is carried out as follows: The timber to be treated is placed in a cylinder or retort, and a vacuum is first formed to extract the air and moisture. The charge of preservative solution is then admitted from a storage tank through a suitable valve, and, as soon as the cylinder is completely charged, pressure pumps are set in motion, the amount of pressure imparted being indicated on suitable pressure gauges. The amount of solution taken up varies of course with different woods; in the case of yellow deal, however, 10 lb. per cubic foot is found to give the best results.

As soon as the desired impregnation has been obtained, the remainder of the solution is forced back into the storage tank, and the timber is then removed from the retort and stacked to dry.

Fig. 110 is a view of Sir W. Burnett & Co.'s "Burnettizing" works situated at Nelson Wharf, Millwall, London, E., and Fig. 111 is a view of the wharf, showing a quantity of "Burnettized" General Post Office telegraph poles.

The pier at Tilbury, shown in Fig. 112 and built in 1906, is constructed of timber treated by this process. The timber used in the refrigerating installation on the

R.M.S.P. Co.'s s.s. *Darro*, launched in 1913, was also treated with "Burnettizine."

THE ZINC-TANNIN OR WELLHOUSE PROCESS.

This process consists in subjecting the wood to be treated to the action of steam in a retort or impregnating cylinder for a period sufficient to open the pores and

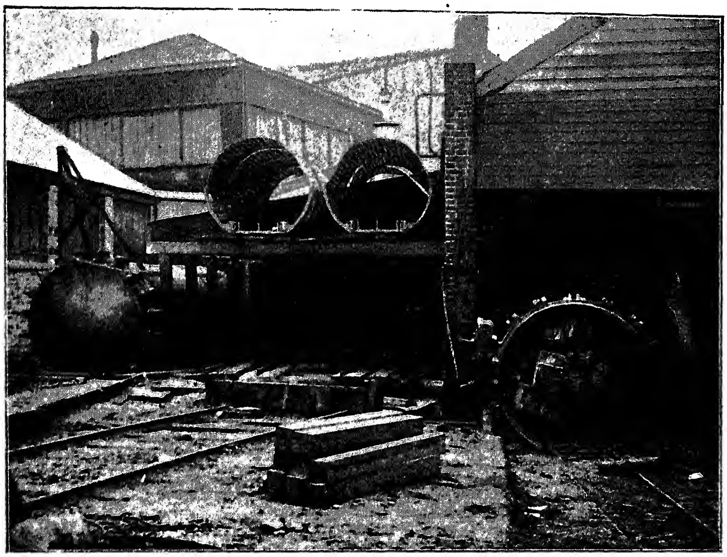


FIG. 110.—Sir Wm. Burnett & Co.'s "Burnettizing" Works, Nelson Wharf, Millwall, London, E.

expel the natural saps, followed by a vacuum of from 18 to 26 ins. to withdraw the vapours and free the wood from the condensed steam and volatilized saps. The antiseptic agent consists of a solution of zinc-chloride of a strength of from 1·5 to 3 per cent,, according to the nature of the wood, with a proportion of dissolved glue equal to one-half of 1 per cent. (The Allis-Chalmers

Company give the proportions as ·5 lb. of dry zinc-chloride plus ·5 per cent. of glue or gelatine per cubic foot of wood.) The solution is held in the retort at a pressure of from 100 lb. to 125 lb. per square inch for $2\frac{1}{2}$ to 6 hours, after which it is forced back into the storage tank and a one-half per cent. solution of tannin or tannic acid ($C_{21}H_{22}O_{17}$) is introduced and held under the same

FIG. 111. View showing "Burnettized" G.P.O. telegraph poles at Sir Wm. Burnett & Co.'s wharf

pressure as before for about two hours. After the withdrawal of the latter the operation is complete.

In some works the practice of introducing the glue in a separate solution is adopted; this necessitates the provision of another storage tank.

The zinc-chloride solution is the same as used in the zinc-chloride process. The glue employed is the

ordinary article of commerce: those glues, however, having the highest percentage of gelatine being preferable. The tannic acid generally consists of an extract of hemlock bark. From 25 to 30 per cent. of pure tannic acid should be present. The amount of the glue and tannin should be one-tenth of the amount of pure chloride used, the proportions of glue and tannin being such as to

FIG. 112.—View of Tilbury pier (1906) built of "Burnettized" Timber.

ensure the absorption of the prescribed amount of pure chloride per cubic foot of wood. The amount of glue should be at least 1 per cent. in weight of the whole amount of chloride solution. The strength of the tannin solution should be at least 1 per cent. in weight of the whole contents holding the tannin solution.

The time occupied in treating the wood by this process

is, for ties or sleepers, omitting steaming, $4\frac{1}{2}$ hours, with steaming, $6\frac{1}{2}$ to $8\frac{1}{2}$ hours; for timber, omitting steaming, $5\frac{1}{2}$ hours, with steaming, $8\frac{1}{2}$ to $13\frac{1}{2}$ hours.

The zinc-tannin process differs only from the "Burnettizing" process in the addition of the glue and the subsequent treatment with tannin solution. The glue and the tannic acid combine and form a leathery and insoluble product claimed to assist in rendering the wood impervious to the absorption and giving off of moisture, and thus to prevent the zinc-chloride from leaking or being washed out.

The plant required is practically the same as that used for the "Burnettizing" process.

The Boucherie or Sulphate of Copper Process.

This method of preserving wood was first mooted in Paris in the year 1840. It consists in impregnating either standing or freshly-cut timber with a solution of sulphate of copper or blue vitriol ($CuSO_4 + 5H_2O$). The preservative is either applied to the tree whilst growing or directly after being felled, in the latter case not more than three months should be allowed to pass before operating upon it. The first method has been abandoned for various practical reasons, and the second is carried out as follows: The trunk of the newly-felled tree is cut into suitable lengths, for say two railway sleepers. A cross cut is then made centrally in each of these lengths for about nine-tenths of its diameter, and a wedge is inserted. A cord is then wound round the cut surface, and the wedge being removed a central chamber is formed which is placed in connection through a flexible pipe with a reservoir containing the preservative, and placed some 25 ft. above the level of the timber,

The fluid, which consists of a 10 or 12 per cent. solution of copper in water, enters this chamber and pressing upon the sap tubes, causes the latter to pass out at each end of the log, itself taking its place. A chemical test enables the operator to ascertain when all the sap has been replaced by the copper sulphate. Boucherie occasionally employed chloride of calcium, pyrolignite of iron, prussiate of iron, prussiate of copper, and various other metallic salts, but as a general rule sulphate of copper is used, except when the hardness of the wood is a desideratum, when it is replaced by pyrolignite of iron, 1 gallon of iron to 6 gallons of water. When flexibility or elasticity is desired chloride of calcium is employed.

Metal caps for forming chambers for the antiseptic solution, which can be secured to the ends of the timber, may be used instead of the above arrangement. These caps are connected to the reservoir.

THE HASSELMANN PROCESS.

The wood, seasoned or steamed, or both, is placed in a retort, which is then closed, and a vacuum pumped for about one hour, the solution being then admitted with the vacuum still on. The solution consists of 1·5 per cent. of copper sulphate ($CuSO_4+5H_2O$), ·5 per cent. solution of aluminium sulphate (Al_23SO_4), and potassium sulphate (K_2SO_4) in proportion in accordance with the condition of the timber. When the retort is about filled, the main valve is shut, and live steam is turned into the solution, through which it is distributed by a perforated pipe, heating the solution to from 118°C. to 126·6°C. (245°F. to 260°F.), and giving a gauge pressure of about 35 lb. per square inch. The wood is kept in this boiling solution for from two to three hours,

when the latter is drained off into a storage tank, or is transferred to another retort.

The main factor in the success of this process is the proper proportioning of the various ingredients in the solution to suit the kind of wood to be treated.

The plant used for the burnettizing process can be used for this process, extra tanks for holding the solution and tanks for mixing the chemicals being, however, required, as well as some slight minor alterations in piping, etc.

THE VULCANIZING OR "HASKINIZING" PROCESS,

The vulcanizing process, also known as the "haskinizing" process, from the name of its inventor, Colonel Haskin, consists in roasting or subjecting the wood, which has been previously dried by steaming, to a temperature sufficiently high to coagulate the albumens contained in it, and in conjunction with pressure also to form new substances. In other words, the high temperature produces a resolution of the woody fibre and sap, and results in the production of wood creosote.

Albuminous food being essential to the life of both fungi and insects, an alteration in the condition of these albumens will render them unfit for the service of the destructive agents. The coagulation of albumens takes place between 71° and 94°C. (160° and 201·2°F.).

An examination of wood treated by the vulcanizing process made by Mr. Chandler, of Columbia College, New York, showed that 11·14 per cent. of new substances had come into existence, viz., ·36 per cent. of neutral oils and turpines, and 10·78 per cent. of resinous acids and other bodies, a large proportion of which consisted of antiseptic and preservative substances.

The plant required comprises one or more air-tight

cylinders or retorts, wherein the timber to be treated can be subjected to heating and pressure, an air-compressor, and an air-circulating engine.

The details of the process are briefly as follows: The retort or retorts being charged with wood to be treated, steam is first injected to remove surface moisture from the timber, the moisture thus extracted being drawn off by means of cocks. Air is compressed in the compressor to a pressure of 200 lb. per square inch, the heat of compression being reduced by sparging or spraying with water, and the moist compressed air is dried and raised to a temperature of between 94°C. and 204·5°C. (201·2°F. and 400° F.), and is forced through the retort by the circulating engine, escaping past a loaded valve, the pressure being kept up by the compressor.

The time required for treatment is from six to ten hours, in accordance with the dimensions of the timber.

This process is claimed to be more effective in the case of green timber.

The Saccharine Solution or "Powellizing" Process.

This process was first introduced by Mr. William Powell, and is hence usually termed the "powellizing" process. The exact composition of the solution used is a secret, but it is stated to consist mainly of sugar with a small percentage of arsenic added, and probably several other ingredients.

The value of saccharine solutions for the preservation of wood is said to have been discovered from the fact that the timber of sugar vats is found to be to all intents and purposes everlasting. It is averred that sugar had never been employed for timber preservation before the idea occurred to Mr. Powell, which is probably true

so far as treatment on a comparatively large scale is concerned.

In this way Mr. Powell made the discovery that when timber is boiled in thin saccharine solutions its character undergoes important changes and its valuable properties are improved. The air in the cells of the wood is expelled during its immersion in the liquid, the albuminous matter is coagulated, and the saccharine solution penetrates into the pores. The excess of moisture is then removed in a desiccating chamber, and after being allowed to cool the wood is fit for immediate use. If desired, poisonous substances may be added to the sugar solution to render the wood proof against insects, including white ants.

The treatment is on the open-tank or immersion system, the treated timber being, however, subsequently subjected to artificial drying. Any description of tank may be used, but a convenient arrangement, especially designed for carrying out the process, comprises a tank of the requisite dimensions fitted with steam-heating pipes and having a water-tight door at one end through which loaded trucks can be run in on a set of tram-lines. The tank having received its charge of timber, this door is closed and cold solution is admitted until the wood is covered. The temperature of the solution is then gradually raised to boiling point, and kept at that temperature for several hours, the exact time varying in accordance with the dimensions and class of wood being treated. The solution is then permitted to cool down, after which it is run off and the timber is passed on into a drying chamber in which the temperature is gradually raised until it has been sufficiently desiccated, when it is removed and is ready for use.

The air in the desiccating or drying chamber is first raised to a temperature of from 55·5°C. to 60°C. (130°F.

to 140°F.), with a humidity of 85–90 per cent., and subsequently this is slowly increased to a maximum of from 74°C. to 76·5°C. (165°F to 170°F.), with a humidity of 35 per cent.

An advantage of considerable value said to be possessed by this process is that green wood may be satisfactorily treated.

A microscopical examination of thin sections of wood treated as above, made by Professor Norman Rudolf, M.Sc., F.I.C., revealed the fact that the cells were swollen up, some being apparently filled with saccharine matter in a non-crystalline form, the saccharine solution having actually become a part of the structure of the wood.

It is stated that the Government of Western Australia, after severe trials, adopted the process and erected large works for treating the timber for their Port Hedland line, over 400 miles in length. Since that time they have acquired extensive forests, and have erected a plant for treating the timber as rapidly as it is felled.

The New Zealand Government are also said to have recently adopted this process, and are able to use the native Rimu wood, hitherto of small value, which is now displacing some millions of imported railway sleepers per annum.

A number of treated sleepers made of Pinus Khasya were laid on the Government railways in Burma in 1907, and according to the report of the officiating Chief Conservator of Forests it has been found necessary to remove only one out of nine up to October, 1910, whereas ten made from the same species of timber but untreated which were laid eight or nine months earlier had to be taken up in 1908 and 1909. Tests with other kinds of wood yielded similar results.

Tests carried out by Mr. C. J. Julius, in Australia,

on jarrah, karri, ironbark, grey, blue, and red gum, mahogany, and other hard woods, are reported to have proved that the treatment rendered the wood from 20 to 35 per cent. lighter while increasing its strength by 30 to 50 per cent. With soft woods such as Oregon pine and kauri the figures were from 30 to 35 per cent. and from 30 to 40 per cent. respectively.

The Guissani Process.

In this process the wood to be preserved is submerged in a bath of anthracene and pitch raised to about 140°C. (284°F.), which temperature is below their boiling point. Directly, however, the wood is placed in the bath the mixture commences to boil, and steam and moisture being given off indicate the passing away of a portion of the constituents of the wood. The cessation of the ebullition—which occurs after from two to four hours—shows that all the sap and moisture has been given off from the wood.

The wood is next transferred into a cold bath of heavy oil of tar, in which it is allowed to remain for about ten minutes, and is afterwards placed in a bath of cold chloride of zinc, in which it is kept until the desired amount has been absorbed.

This process also is claimed to be especially suitable for sleepers.

The Crésol-calcium Process.

This process, which has been recently brought out by Messrs. F. Friedeman and G. von Heidenstam, consists in the use of an agent composed of a mixture of crésol and milk of lime, the proportions given being 15 grs. of burnt lime (90 per cent. to 95 per cent.), 46 cc. of crésol,

containing at least 95 per cent. of tar-acids, and 500 cc. of water.

The theory of the inventors is that 2 ozs. of creosote per cubic foot is sufficient for purposes of impregnation, the larger quantities ordinarily employed being required owing to the difficulty of ensuring even distribution. By mixing crésol with milk of lime they claim to bind the tar-acids by transforming them into salts soluble in water but not volatile. Ordinarily it is impracticable to use tar-acids for impregnation, or to use them in water solutions owing to their being too volatile. It is pointed out that it is a generally accepted fact that tar-acids are efficacious agents for timber preservation.

The plant required for carrying out the above process may be any of those ordinarily employed for impregnating timber by the pressure or pneumatic methods.

The Aczol Process.

This process, which has been developed by the Cie. Gle. l'Aczol of Brussels, consists in the employment of a preservative compound containing certain metallic ammoniates which are claimed to so act as to completely fix in the wood treated those phenols forming the active constituents of creosote, whilst at the same time themselves possessing considerable preservative value. The compound is supplied in a highly concentrated form, containing 150 times the percentage of phenols and ten times the percentage of metallic salts required to sterilize gelatine, which latter is more susceptible than ligneous matter to fungoidal attack. According to the makers an injection of a 3 per cent. solution of concentrated aczol in water completely and indefinitely protects wood from decay. The toxic ingredients in the solution are also said to form

an absolute preventative against the attacks of the teredo navalis, the white ant, and other insect pests.

The treatment may be effected by simple immersion or steeping, the time required being from three to ten days, according to the species and condition of the wood. Where large quantities of timber, however, require impregnation, a simple form of pressure plant will be found advisable. The thin aqueous solution of aczol penetrates easily to every part of the wood, and when once introduced it is said to gelatinise and partly hydrolise the cellulose, forming over every tissue and fibre a skin combined intimately with the surface layers, and containing antiseptic ingredients, and finally hardening into a tough, non-hygroscopic and insoluble compound, unaffected by hot or cold water, carbonic acid, or by any natural constituent of the atmosphere or the soil. This fixation follows the disappearance of the volatile alkaline solvent, and the cementing together of the fibres and tissues is claimed to strengthen the wood to an appreciable extent.

In proof of this latter assertion the proprietors state that according to results obtained by the Belgian State Testing Department the crushing strength of various samples of wood treated with aczol solution showed a 95 per cent. increase, whilst the compressive strength of other samples of aczolled wood was twice that of similar wood creosoted, and about 10 per cent. greater than that of similar timber treated with copper sulphates. As regards resistance to tearing, aczolled wood was found according to the above tests to be 62 per cent. stronger than creosoted wood, and 47 per cent. stronger than wood treated with copper sulphates.

Further advantages claimed for this preservative agent are that by suitable impregnation wood can be rendered water-proof and non-inflammable, that its weight is only

slightly increased, that it remains clean and non-odorous and can be painted or polished, that no salts are introduced or formed in the wood injurious to the latter or to iron or other metals, and that the insulating value of the wood is not destroyed. It is also to be noted that owing to the preservative being supplied in a very concentrated form intended to be afterwards diluted with water, there is a considerable saving in the cost of carriage.

Naphthalene.

Naphthalene or Naphthalin ($C_{10}H_8$) has been employed as a preservative for a couple of decades or longer, and is said to give satisfactory results. It is stated by S. H. Collins, M.Sc., and Dr. A. A. Hall, M.Sc. (*Journal of the Society of Chemical Industry*), to penetrate easily into the wood, and to appear to evaporate very slowly, and as a preservative to appear to be at least equal to creosote. It possesses the advantage of imparting a nice colour to the timber, and, moreover, does not render it disagreeable to handle.

Tests carried out by the above experimenters with posts treated with naphthalene showed that very large quantities of the preservative were still present in the wood after fourteen years' use, and that the wood was still in a good state of preservation.

It is also asserted that green timber can be treated with naphthalene quite as effectively as air-dried timber.

Natural Oils as Preservative Agents.

Recent experiments have demonstrated that natural oils can be used as preservative agents with a fair amount of success. It does not appear that such oils possess any antiseptic properties, but they serve the purpose of

stopping up the open wood cells with a substance which becomes solid under ordinary temperatures, thus preventing heat, moisture and air from penetrating into the wood, and obviating the assistance which they render to the decay-producing organisms in getting to work. This proposition seems reasonable enough, as it is generally held by timber experts that, in order to produce decay, moisture and heat must be present at the same time with access to the air.

The practice of the Atchison, Topeka and Santa Fé Railway is to use crude Californian oil of a very low specific gravity with about 75 per cent. of asphaltum, and the remainder light oils, which vaporize on being heated. The oil is heated to 82°C. (179·6°F.) and is forced into the wood at a pressure of from 150 lb. to 200 lb. per square inch. At normal temperatures the oil is of about the consistency of molasses, but when heated it becomes sufficiently fluid to allow of its penetration into the pores of the wood. A slight vacuum is applied at the close of the operation, which seals the pores and admits of the wood being handled without difficulty.

When the process is used for sleepers the amount of oil injected is from 4 to 8 gallons per sleeper, and excellent results are said to be attained as regards the prolongation of the life of the sleepers.

The above railway company, it is said, were induced to experiment with crude oil as a preservative agent owing to finding the life of untreated sleepers to be greatly prolonged on portions of their track on which the oil was sprinkled to keep down the dust: the coating of oil which spread over the tops of the sleepers keeping off moisture.

CHAPTER IX

Various Proprietary and other Preservative Solutions.

Anthrol—Atlas — Béllit — Carbolineum— Dyphenin—Green Oil—Hylinit—Jodelite—Microlineum—Microsol—Sideroleum —Solignum—Sotor—Stop-rot—Wilcoo—Various other Processes and Solutions.

Various Proprietary Preservative Solutions.

THE following are a few of the numerous preparations now on the market:

Anthrol.

This is a proprietary antiseptic solution, made by the Anthrol Company, which can be used as a paint, or for the immersion or open-tank process. The solution is preferably employed in a heated condition.

Atlas Preservative Solution.

The composition of this solution is a secret. It is said to cause slight irritation of a passing nature, contact with the skin should therefore be avoided. The treatment of timber with this agent consists in the immersion in a bath of the cold solution of a strength of from 15 to 25 per cent. for a period of time dependent upon the size and nature of the wood to be treated. In the case of sleepers from 24 to 36 hours will be required.

After the treated timber is dry, it should, according to the makers, be given a coat of hot gas-tar, probably to prevent leaching.

Béllit.

This is also a proprietary solution possessing antiseptic or preservative qualities, and consisting of a 2 per cent. solution of dinitro-benzol and mineral oil. It has a boiling point of 300°C. (572°F.). The mode of application is the same as with "Anthrol."

Carbolineum.

Oils obtained from the distillation of coal-tar consisting of such oils heavier than water which, with tar-acids, help to form creosote. There are two well-known grades of this oil on the market, carbolineum Avenarius, a preservative solution introduced over thirty years ago by Mr. Avenarius, and carbolineum "marque de lion."

An analysis made by Dr. Filsinger of the first mentioned (see *Préservation des Bois*, Henry) shows it to contain oils distilling at 230°C. (446°F.), and to possess a density of 1·128, viscosity at 17°C. (62·6°F.), as compared with water 10, to contain 10·6 per cent. per volume of oils distilling between 230°C. (446°F.), and 270°C. (518°F.), and 12·2 per cent. of oils coming over between 270°C. (518°F.) and 300°C. (572°F.). The residue is a thick, limpid, red-brown mass.

Carbolineum heated to from 65°C. to 94°C. (149° to 201·2°F.) can be either applied to the wood with a wire brush, or the timber to be treated can be immersed in a bath of the warm solution according to the open-tank method, the best temperature for the bath being 95°C. (203°F.), and the timber being allowed to remain in soak for from 5 to 15 minutes, according to dimensions and character.

Experiments have demonstrated that, in the case of hard woods such as oak and beech, the amounts absorbed by the woods in a bath of carbolineum at a temperature

of 60°C. (140°F.) were not increased to any appreciable extent by prolonging the immersion to twenty minutes. It also appears that an increase in the temperature of the bath to 80°C. (176°F.) and over has no effect upon the amount of the oil absorbed by the wood.

Dyphenin.

A proprietary agent supplied in the form of paste, which for use is first stirred with a stick and is then mixed with water in which the composition has a high degree of solubility. According to the makers an application of a 2 per cent. solution obtained by mixing the contents of a 2 lb. tin of dyphenin with 5 gallons of water will, as a rule, be found satisfactory. For the ends of beams, etc., a 4 per cent. solution will be required. The solution is applied either by steeping or impregnation by steaming, or by means of a brush, better penetration being secured when it is used hot. The paste may in the latter case be either dissolved in hot water or the solution may be heated in a small boiler.

This preparation is claimed to be a specific against the attacks of dry-rot, and not to have any tendency to increase the inflammability of the wood.

Green Oil.

This is a product of creosote, and is used in a similar manner to carbolineum.

Hylinit.

This preparation is a proprietary article, the composition of which is a secret.

The strength of the solution for treatment by immersion is given by the makers as 5 per cent., and the wood should remain in the bath for 24 hours.

Jodelite.

Another proprietary antiseptic, used in a similar manner to carbolineum.

The treatment by open-tank method is stated by the maker to take from 10 to 40 minutes, in accordance with the density of the wood. The solution should be heated to from 82°C. to 94°C. (179·6°F. to 201·2°F.).

Microlineum.

A proprietary antiseptic solution claimed by the proprietors to prevent dry-rot, and to protect wood from the ravages of the white ants (thermytes) so destructive in hot climates. This preparation is also stated to act as a safeguard against the teredo navalis, and it also forms a permanent stain of various colours. It is applied either by means of a brush or by steeping.

Microsol.

According to an analysis made by Professor Arth (*Préservation des Bois*, Henry), this solution consists of sulphate of copper, 70 per cent., in crystalline and powdered form, sulphate of soda, sulphate of lime, small trace of free silicate, and a copper salt of sulphophenol.

The treatment is the same as with carbolineum, the strength of the solution varying from 2 per cent. to 4 per cent, and the time required being 24 hours or more immersion, according to the nature, etc., of the wood.

This preparation is well spoken of on the Continent.

Sideroleum.

This preparation consists of a blend of hydrocarbon oils which is claimed to possess considerable penetrative powers, and to have the property of carrying the carbon into the pores of the wood without employing pressure.

This antiseptic agent is stated to render sappy wood hard and rot-proof. It is applied cold by means of a brush and imparts a pleasing brown finish to wood (Anderson).

Solignum.

A proprietary antiseptic solution made by Major & Co., and applied with a brush, either cold or when climatic conditions render it advisable heated to from 71°C. to 82°C. (160°F. to 180°F.). This solution has a tendency to work downwards.

Sotor.

This is a preparation designed for the protection of wood exposed to the action of sea water from the attacks of marine worms (teredo navalis), and for preventing decay (Peters).

Stop-rot.

Another proprietary antiseptic which is claimed to be a preventative of decay and of dry-rot, and also to render wood proof against the attacks of insects. This solution should be preferably applied hot, as it soaks deeper into the wood and dries quicker than when used cold. It is said to be especially suitable for use in tropical climates (Pilchers).

Wilcoo.

A patented composition for preventing decay in timber. It is stated by the proprietors to possess great powers of penetration and to enter the knots, cracks, and crevices of the wood, driving out all the sap, and rendering it rot-proof. They claim that this preservative solution is a preventative of dry-rot fungus and mildew, an excellent disinfectant, and destroys or drives away all vermin. The solution is applied with a brush (Cooper).

Various Other Processes and Solutions.

Amongst the numerous other processes, materials, and patent or proprietary and other preservative solutions, many of which have been used with some success, mention may be made of the following:

Heinemann's patent provided for first boiling the wood in a weak solution of carbonate of soda or other alkali or dilute hydrochloric acid until such time as the solution ceased to abstract colour from the wood. In this manner the nitrogenous matter is known to be removed, and it is stated that, after drying, the wood may be employed in situations where it will not be exposed to moisture. In the case of railway sleepers, etc., the wood is subjected to a further treatment, consisting in heating it in closed chambers with resin and water, the combined steam and resinous vapour from the latter penetrating the wood. The steam is subsequently got rid of by cooling and sudden reheating.

Reubbit Nowotny suggests the use of fluorides in lieu of creosotes and zinc chlorides (*Zeitschrift für Angewandte Chemie, Berlin*).

For fire-proofing it is stated that soluble glass may be substituted for the resin.

Szerelmey's patent consists in first immersing in a boiling solution of potash and lime and treating with cold dilute sulphuric acid; secondly in coating with compounds of petroleum, asphaltum, lime, zopissa, and sulphuric acid.

Soaking in lime water is recommended for preserving from dry-rot and effects of weather, also superficial carbonization by a gas flame or flame of a heavy hydrocarbon oil.

Hubert recommends ferric oxide as being the best agent

for preserving wood. For the impregnation of the wood he suggests that long thin nails be hammered into it, or that iron bands be fixed round it, which will gradually rust, and, it is stated, impregnate the wood in a uniform and permanent manner.

The method of preserving suggested by L. S. Robbins consists in removing the surface moisture by heat, then saturating with vapours of coal-tar, resin, and other oleaginous substances.

Van der Weyde's process for preserving wood consists in using a dilute solution of silicate of potash, one or two subsequent coats of a stronger solution being applied after the first one has dried.

Champy (Baron) proposed to preserve wood by dipping it in a green condition in tallow at a temperature of 94° Cent. (201·2°F.). The water and gases being driven out the melted tallow penetrates the pores of the wood under atmospheric pressure.

The use of chloride of sodium as a preservative agent is stated to render the wood flexible when seasoned. Earthy chlorides are employed for rendering wood incombustible.

Phosphate of baryta (barium monoxide or baryta, BaO.) formed within the fibres of the wood has also been used to prevent decay. The wood is first steeped in a solution composed of 7 per cent. of phosphate of soda, and when dry is treated again with a solution consisting of 13 per cent. of chloride of barium ($BaCl_2$), a soluble salt which is one of the most important compounds of barium.

Behr's patent comprises boiling the wood in a solution of borax.

Davison and Symington remove moisture from timber by means of a desiccating hot blast,

Payen's process consisted in immersing green wood in melted resin, which, he claimed, after the water and gases had been expelled, entered the pores of the wood under atmospheric pressure.

Chapman employed a special method of treatment with sulphate of iron or green vitriol ($FeSO_2 + 7H_2O$.).

A process said to be used in Montreal consists essentially in employing an emulsion of waste sulphite liquor and creosote oil, to which may be added soluble salts, such as chloride of zinc, mercuric chloride, copper sulphate, etc.

Beaumartin's process consists in impregnating wood with various metallic salts, on the principle of osmosis produced electrically. According to *L'électricien*, Paris, 1906, the timber is first placed in a retort, and copper or zinc sulphate, or sodium silicate, is injected under pressure. The wood is then subjected to the action of an alternating current of electricity, by means of which the state of the fibres and sap, and of the injected salts, is so modified that the latter combine with the organic elements of the sap and encrusting matter, and form insoluble salts which remain fixed on the fibres and prevent putrefaction. The alternating currents, moreover, it is claimed, destroy all vegetable and animal germs, and cause the fibres themselves to be so transformed as to increase both their tenacity and their mechanical resistance.

Zinc-chloride ($ZnCl$) and sodium-fluoride (NaF) mixed in equal quantities are recommended by Mr. H. B. Malenkovic; the strength of the solution, which is used according to the open-tank system, is 3·5 per cent. $ZnCl$ and 3·5 per cent. NaF.

For mine timber the United States Forest Service have experimented with (1) a preservative agent consisting of creosote and carbolineum Avenarius heated to a tempera-

ture of 82°C. (180°F. nearly) and applied in two coats with a brush; (2) a bath composed of a 15 per cent. solution of common salt and a 6 per cent. solution of zinc-chloride and creosote, the wood being immersed or steeped in an open tank in successive hot and cold baths of this agent; (3) treatment in a closed retort in a vacuum and under pressure, the agent used being zinc-chloride solution and creosote.

In a modification of Blythe's system the wood is submitted in a retort to the action of superheated steam at a minimum temperature of 200°C. (392°F.), which steam is caused to pass over a reservoir containing creosote, the products of condensation, comprising water and creosote, being then drawn off, the retort filled with a charge of creosote, and steam pressure applied, the creosote being extracted from the water evacuated during the first stage for further use.

A system used in France many years ago, and said to have given excellent results, consists in placing the wood in a tank with a layer of quicklime on the top, which lime is slowly slaked with water. The time required for this treatment is about seven days, and the timber so treated is said to acquire a remarkable degree of hardness.

A process used in Belgium consists first in exposing the wood in a retort to a vacuum and afterwards impregnating under pressure with an agent formed by a two-third solution of gutta-percha to one-third of paraffin, and heated until sufficiently liquid.

An infusion of quassia wood has been used with some success.

A strong solution of sulphate of iron and sulphate of copper, injected under pressure (Boucherie and Sage and Fleury-Pironnett processes).

A steaming vacuum-pressure process, sulphate of

copper solution (Sage and Fleury-Pironnett). This process should be carried out within about ten days of felling the timber, and the life of the wood is affected by the nature of the soil it may come in contact with.

A PRESERVATIVE SOLUTION NAMED CRÉSOYLE.

Tungstate of soda and water solution of a specific gravity of 1·2 (Jones's process).

Sulphur immersed in nitric acid and distilled (Evelyn's process).

Hot anthracene oil used at Dortmund collieries.

To every gallon of water 3 ozs. croton tiglium seeds, 3 ozs. margosa bark, 3 ozs. sulphur, 2 ozs. blue vitriol, solution for preventing attack by white ants.

Pfister's method of diffusion in freshly-hewn wood. Impregnation with molten sulphur.

Faleir's method of destroying the fungi of dry-rot in buildings affected by heating beyond 40°C. (104°F.), which is the temperature at which the myceleum of the merulius is killed. Owing to the fact that wood is a poor conductor of heat, it is considered desirable to raise the temperature of the entire building to 42°C. (107°F.), and to maintain this temperature for at least two hours. It is important to be quite certain as to the exact nature of the growth, as if the fungi be grown inside the wood heat will only expedite the work of destruction, as fungi of this class flourishes more actively at the temperature fatal to the dry-rot fungus.

A paint which it is claimed acts as a preventative to dry-rot consists of the following ingredients: Wood tar, 1 part; train oil, 1 part; oil of cassia, 1 part. A thin coat to be applied to the wood.

A combined seasoning and preservative process used in France consists of a tank charged with a solution

composed of 5 per cent. resin, 10 per cent. borax, a trace of carbonate of soda. The wood is stacked on a lead plate in the bottom of the tank, and another lead plate is placed on the top, the former being connected with the positive pole and the latter with the negative pole of a dynamo. The current passes from the upper plate through the wood, by which it is said the sap of the wood is driven out and the resin and borax take its place, filling up the cells and interstices.

St. Preuve's process consists in forcing steam into the pores of the wood, and subsequently by causing a condensation of this steam, drawing or sucking in the preservative solution.

Brochard and Watteau's process is a simple one. The wood to be treated is placed in a suitable cylinder or retort and the door being closed it is filled with steam. A vacuum, or rather a partial vacuum, is then produced by forcing in a cold preservative solution composed of salt, etc.

Mann and McPherson, for preventing the attacks of white ants, recommend a composition of gambir made from gutta-gambir, the juice of the Uncaria gambir inspissated by decoction, strained, suffered to cool and harden, and either made into balls or cut into cakes. The composition above referred to consists of three parts of gambir melted in twelve parts of dammer oil over a slow fire, one part of lime being then well stirred in, and the whole then ground down, after which it should be again heated, and a small proportion of oil sufficient to bring it to a proper consistency added, when it can be applied to the surface to be protected like paint.

A proprietary composition known as "loracine" (R. Lehmann & Co., Ltd.) is claimed by the proprietors to stop shakes and to prevent wood from splitting.

The following list gives the names of some of the substances which have been patented for use as preservative agents:

Acetate of copper; acid vitriolic; acid of tar; alum; animal glue; animal wax; arsenious acid; asphaltum; borax; carbonate of baryta; carbonate of potassa; carbonate of soda; chloride of sodium; chloride of zinc; creosote; corrosive sublimate; lime, quicklime, water; metallic sulphurets decomposed by an acid or a metallic salt; marcosites mundic and barytes; mother water of marshes; muriate of soda; nitrate of potassa; oils, vegetable, animal, mineral; peat moss; phosphate of baryta; potash and lime; pyrolignite of iron; refuse liquors of chlorine works; resin; silicate of potash; salt, neutral; salt, odenites; smoke; sugar; sulphate of alumina; sulphate of baryta; sulphate of copper; sulphate of iron; sulphate of lime; sulphate of soda; sulphuric acid; tallow; tar; zopissa.

CHAPTER X

The Absorption Limit and Life of Preserved Wood.

Amounts of Preservatives absorbed by various Woods—Life of Preserved Wood.

Amount of Preservative absorbed by various Woods.

THE practice of Mr. Bethel, the inventor of the creosoting process, was to use from 8 to 10 lb. of creosote oil for land purposes and about 12 lb. for marine use, per cubic foot of wood, and no timber was allowed to leave his works without being tested to ascertain whether it had absorbed the proper amount of the preservative. The amount found by Bethel to be absorbed by yellow pine is about 11 lb. per cubic foot, and by Riga pine about 9 lb. per cubic foot.

In India the amount of absorption by hard woods, such as terminalia, tomentosa, and mesua ferrea, is stated to be 3 lb. per cubic foot; moderately hard woods, such as dipterocarpus tuberculatus, etc., 6 lb. per cubic foot; and soft woods, such as pinus excelsa, pinus longifolia, etc., 10 lb. per cubic foot.

In France the woods most commonly used for sleepers are oak, beech, or pine; but fir, larch and chestnut are occasionally employed. The French practice is to impregnate oak sleepers of about 3 cubic feet with from 8·8 to 12·3 pints of creosote; beech or pine sleepers,

with about 44 pints of creosote each, the question of expense, however, frequently rendering it desirable to do with a less amount. According to the writer of an article which appeared in 1895 in the *Revue Générale des Chemins de Fer*, the weights of creosote injected per sleeper by the principal French lines for different kinds of wood are as follows:

Description of Wood.	Railway.	Lb.
Oak . . .	All	11 to 15·5 (absorp. limit)
Beech . .	Northern. . . .	28·5
,, . .	Western	33 to 35·25
,, . .	Paris-Lyons-Mediterranean	35·25
,, . .	Eastern	53
Pine. . .	Midi	26·5 (absorption limit)
,, . . .	Orleans	31 ,,
,, . . .	Paris-Lyons-Mediterranean	26·5 ,,

Present practice tends to the injection of an increased amount of oil per sleeper. A report, presented at the International Railway Congress in 1895 by Mr. Harzenstein, states that the practice on the various lines in this country was to inject from 7 to 10 lb. of oil per cubic foot, with an average life of sixteen to twenty years, an injection of from 7 to 8 lb. per cubic foot giving an average life of from twelve to fifteen years. The amount inserted, according to later practice, is from 30 lb. to 35 lb. per sleeper. In France 48·4 lb. of oil per sleeper is used as a minimum.

On Indian railways the amounts of oil injected into sleepers of various woods are as follows: beech and pine, 10 lb. of creosote oil per cubic foot; harder woods, such

as oak, 3 lb. per cubic foot; piles of coniferous woods, 20 lb. per cubic foot. When chloride of mercury or corrosive sublimate is used as an antiseptic, the amounts used per cubic foot are: for hard wood, 3 lb.; moderately hard, 6 lb.; and soft, 10 lb.

Mr. J. R. Baterden states (*Proceedings Inst. C.E.*, 1904) that he has experienced no difficulty in getting into pitch pine 7 lb. of creosote oil per cubic foot.

Absorption Limit of Hard Woods. (From various Authorities.)

		Per cubic foot.
Blue Gum (Eucalyptus Globulus)	Australia	$\frac{3}{4}$ lb.
Ironwood (Bumelia lycioides)	Eastern U.S.	1 lb.
Jaman	India	$\frac{3}{4}$ lb.
Locust (Robinia pseudacacia)	United States	$\frac{3}{4}$ lb.
Mahogany (Swietenia mahogoni)	Central America, Cuba	$\frac{3}{4}$ lb.
Oak (Quercus robur, etc.)	Europe, etc.	4–5 lb.
Teak (Oldfieldia Africana)	West Africa	$1\frac{3}{4}$ lb.
,, (Tectona grandis)	India	$1\frac{3}{4}$ lb.
Sâl or Saul (Shorea robusta)	,,	1 lb.
Sisso (Dalbergia Sisso)	,,	$3\frac{3}{4}$ lb.
Sundri	,,	$2\frac{1}{4}$ lb.
Swan River Wood	Australia	$1\frac{3}{4}$ lb.

In the United States the usual amounts of creosote oil specified to be injected are as follows: For railway ties or sleepers, from 10 to 12 lb. per cubic foot; for dimension timbers, from 15 to 20 lb. per cubic foot; for piles, from 20 lb. to 30 lb. or more per cubic foot. Other experts advise the injection into the wood, in the full-cell creosote process, of from 6 lb. to 12 lb. of creosote oil per cubic foot, in the case of railway ties or sleepers, and from 10 lb. to 20 lb. per cubic foot in the case of timber and piling.

The practice in the U.S. is to inject from 6 to 14 lb. of creosote oil per cubic foot for hard woods, and from 13 to 22 lb. per cubic foot for soft woods. At the Gales-

burg plant of the C.B. & Q.R.R., according to the supervisor Mr. Meyer, red oak and beech ties given one hour preliminary steaming at 5 lb. pressure and treated to refusal gave an average absorption of 12·21 lb. of creosote oil per cubic foot. Soft maple, sweet gum, white gum, pine, and tupelo gum, also given an hour's preliminary steaming at 5 lb. pressure per square inch, gave an average absorption of 18·49 lb. per cubic foot.

In the Rueping and Lowry processes the wood is first impregnated with from 10 lb. to 12 lb. of creosote oil per cubic foot, the amount left in the wood fibres on leaving the retort being from 2 lb. to 6 lb. per cubic foot.

Mr. J. B. Card, writing to the *Engineering News* (New York) in October, 1908, remarks that the treatment of sleepers with small doses of creosote oil has not been a success either in the United States or in Europe.

In Germany the usual amount of creosote oil used for the impregnation of sleepers is 12 lb. per cubic foot.

Messrs. Richard Wade, Sons & Co., Ltd., who use the Rueping process on an extensive scale for treating telegraph poles, give the following absorption in a test[1] made to ascertain the amount of creosote oil absorbed and subsequent loss through leaching:

Absorption of creosote oil per cubic ft.	Loss by leaching after 8 months.
10·85 lb.	7·23 lb.
15·98 „	8·87 „
13·98 „	7·41 „
18·89 „	9·30 „

[1] See page 200 for full particulars of test.

WEIGHT OF TIES OR SLEEPERS TREATED WITH CREOSOTE OIL

(Allis-Chalmers Company)

KIND OF TIE.		HEWN TIES.				SAWED TIES.			
Size of Tie		6″x8″x8′-0″	6″x8″x8′-6″	7x″9″x8′-0″	7″x9″x8′-6″	6″x8″x8′-0″	6″x8″x8′-6″	7″x9″x8′-0″	7″x9″x8′-6″
Cubic feet in each Tie		2·62	2·78	3·45	3·66	2·67	2·83	3·50	3·72
Weight of Green Tie in lb.		137	145	180	191	139	147	182	194
Weight of Seasoned Tie in lb.		105	112	138	147	107	114	140	149
Treatment with 4 lb. of Creosote Oil	Gallons per Tie	1·20	1·28	1·58	1·67	1·22	1·30	1·60	1·70
	Pounds per Tie	10·48	11·12	13·80	14·64	10·68	11·32	14·00	14·88
	Weight Treated Tie	115·48	123·12	151·80	161·64	117·68	125·32	154·00	163·88
Treatment with 6 lb. of Creosote Oil	Gallons per Tie	1·80	1·91	2·42	2·51	1·85	1·94	2·40	2·53
	Pounds per Tie	15·72	16·68	20·70	21·96	16·02	16·98	21·00	22·32
	Weight Treated Tie	120·72	128·68	158·70	168·96	123·02	130·98	161·00	171·32
Treatment with 8 lb. of Creosote Oil	Gallons per Tie	2·40	2·53	3·16	3·47	2·44	2·59	3·20	3·40
	Pounds per Tie	20·98	22·24	27·60	29·28	21·36	22·64	28·00	29·76
	Weight Treated Tie	125·98	134·24	165·60	176·28	128·36	136·64	168·00	178·76
Treatment with 10 lb. of Creosote Oil	Gallons per Tie	3·00	3·12	3·60	4·18	3·05	3·24	4·00	4·25
	Pounds per Tie	26·20	27·80	34·50	36·60	26·70	28·30	35·00	37·20
	Weight Treated Tie	131·20	139·80	172·50	183·60	133·70	142·30	175·00	186·20
Treatment with 12 lb. of Creosote Oil	Gallons per Tie	3·59	3·82	4·73	4·52	3·66	3·88	4·80	5·10
	Pounds per Tie	31·44	33·36	41·40	43·92	32·04	33·96	42·00	44·64
	Weight Treated Tie	136·44	145·36	179·40	190·92	139·04	147·96	182·00	193·64

AMOUNT OF CREOSOTE LEFT IN TIMBER AFTER 10 TO 25 YEARS' USE

Collins & Hall, *Journal of the Society of Chemical Industry.*

Species of Timber.	Treated with Creosote Oil.				
	Ash.	Beech.	Scots pine top.	Scots pine middle.	Scots pine point.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Preservative per 100 parts of wood	10·72	15·77	10·85	30·5	17·6
	Fractions per 100 parts of preservative.				
Temperature deg. C. :—					
100–170	0	0	0	0	0
170–205	0	0	0	5·2	1·0
205–245	11·3	14·1	35·8	20·0	22·2
245–271	12·4	11·4	13·0	15·1	24·2
271–316	76·3	74·5	24·2	24·4	30·0
Pitch	—	—	27·0	35·3	22·6

AVERAGE ABSORPTION OF GREEN AND DRY TIES STEAMED AT 20 LB. PRESSURE 3½ HOURS AND SUBJECTED TO 1 HOUR VACUUM

(J. B. Card, *Proc. Am. Wood Preservers' Association*, 1915.)

Kind of Wood.	Weight per per cub. ft.	Solution absorbed in lb. per cub. ft.	Gain : per cent.
Pin Oak	63·1	6·4	10·1
Red Oak	56·1	10·4	18·6
Black Oak	55·5	10·3	18·5
Water Oak	54·3	11·6	21·4
Beech	55·1	5·2	9·35
Sweet Gum	48·4	2·4	5·0
Maple	42·3	24·0	57·5
Black Gum	41·7	14·7	35·5
Cypress	42·2	25·9	61·3
Red Elm	45·4	20·0	44·0
Hickory	62·7	2·9	4·7

ABSORPTION OF CHLORIDE OF ZINC

(W. F. Goltra, *Proc. Am. Wood Preservers' Association*, 1915.)

Species.	Solution Range.	Pounds Average.	Dry Salt Range.	Pounds Average.
Oak . . .	10 to 50	30	·30 to 1·50	·90
Beech . . .	20 to 65	42	·60 to 1·95	1·275
Pine . . .	30 to 90	60	·90 to 2·75	1·825

Note.—Solution 3 per cent. strong, i.e., 3 lb. of dry salt dissolved in 97 lb. of water.

The practice on the continent is to specify the degree of strength of the solution according to Beaumé's hydrometer. The Imperial railways of Alsace-Lorraine, Germany, and the Bavarian railways specify that the solution must have a strength of 3·5° Beaumé—1·0244 spec. gr. at a temp. of 15°C. (59°F.). The Prussian railways specify a strength of 3·0° Beaumé at a temp. of 14° Réaumur (63°F.).

EQUIVALENT STRENGTH OF CHLORIDE OF ZINC SOLUTION FOR DIFFERENT DEGREES BEAUMÉ AT VARIOUS TEMPERATURES

(W. F. Goltra, *Proc. Am. Wood Preservers' Association*, 1915.)

Divisions on Beaumé Hydrometer.	Temperature Degrees Fahr.	Equivalent Strength per cent.
2	70	1·75
2·5	90	2·50
3	60	2·42
3	70	2·59
3	80	2·75
3	90	2·92
3	110	3·33
3·5	60	2·83
3·5	70	3·00
3·5	80	3·18
3·5	90	3·37
3·5	110	3·83

Strength of solution should be sufficient to prevent decay and preferably somewhat more to allow for leaching. Too strong a solution may injure the fibre of the wood.

WEIGHT OF TIES OR SLEEPERS TREATED WITH ZINC-CHLORIDE

(Allis-Chalmers Company.)

KIND OF TIE.	HEWN TIES.				SAWED TIES.			
Size of Tie	6"x8"x8'-0"	6"x8"x8'-6"	7"x9"x8'-0"	7"x9"x8"-6"	6"x8"x8'-0"	6"x8"x8'-6"	7"x9"x8'-0"	7"x9"x8'-6"
Cubic feet in each Tie	2·62	2·78	3·45	3·66	2·67	2·83	3·50	3·72
Weight of Green Ties in lb.	137	145	180	191	139	147	182	194
Weight of Seasoned Ties in lb.	105	112	138	141	107	114	140	170
Weight of Dry Zinc per Tie in lb.	1·31	1·39	1·72	1·83	1·34	1·43	1·75	1·86
Weight of Solution per Tie in lb.	76·50	81·00	101·00	107·00	77·80	82·50	102·00	109·00
Total Weight Treated Tie	181·50	193·00	239·00	248·00	184·80	196·50	242·00	279·00

Note.—The weight of timber depends upon the class of woods, but for estimating purposes assume that the average weight of green timber is 52 lb. per cubic foot and seasoned timber 40 lb. per cubic foot. Creosote oil weighs 8·75 lb. per gallon.

Treatment with ·5 lb. of zinc-chloride per cubic foot, zinc-chloride solution at 8·46 lb. per gallon. Specific gravity 1·015. Absorption about 45 per cent.

In the U.S. the amount of chloride of zinc solution found to be absorbed per cubic foot of the wood when treated to refusal after one hour's preliminary steaming at 5 lb. pressure is given as from 14 to 21 lb. per cubic foot for hard woods, and for soft woods from 19 to 27 lb. per cubic foot. At the Galesburg plant, according to Mr. Meyer, red oak and beech ties steamed for two hours at 10 lb. pressure and treated to refusal with a 4 per cent. solution of zinc-chloride absorbed an average of 16·75 lb. per cubic foot. White elm, birch, soft maple, pine, and cypress steamed for one hour at 5 lb. pressure and treated to refusal with a 2·25 per cent. solution of zinc-chloride absorbed an average of 24·31 lb. per cubic foot.

Ernest Bateman, in an article entitled "A Method for Determining the Amount of Zinc Chloride in Treated Wood" (*Ind. & Eng. Chem.*, January, 1914), describes methods that have been tried for separating inorganic solubles from organic matter, and especially refers to the Fahlenburg and another accurate method for determining zinc.

Of aczol solution the makers recommend for ordinary use an injection of about 2 oz. of concentrated aczol per cubic foot. For wood especially exposed to be attacked by rot, such as pit props, etc., from 4½ oz. to 7½ oz. of concentrated aczol per cubic foot is said to be desirable.

Life of Preserved Woods.

Mr. V. Herzenstein, in the Bulletin of the International Railway Congress (July, 1910), from information collected from a number of railway companies, gives the average life of creosoted sleepers to be as follows :

Description of Sleeper.	Main Line. Years.	Sidings. Years.	Total Years.
Creosoted Pine	15	5	20
,, Oak	18	7	25
,, Beech	20	10	30

Mr. Hausser, of the Midi Railway Company, France, in his report to the Seventh Session of the Railway Congress, says: "Although it is very difficult to lay down a rule that would be at all generally applicable, it may, however, be said that there is a unanimous opinion that pickling or preserving materially lengthens the life of sleepers, approximately doubling it in the case of oak, tripling it in the case of pine, and quintupling it in the case of beech."

A record of the removals of ties or sleepers on the New Mexico and Colorado divisions of the Aitchison, Topeka and Santa Fé Railway, carefully kept from 1897 to 1907, shows the average life of these sleepers, which were treated on the zinc-tannin or Wellhouse process, to be 13·11 years. The number of ties or sleepers treated in 1885 was 111,503. At the end of 1907 the records showed that 77,000 had been removed twenty-one years after laying down, thus leaving 34,503 as having been removed during the years when no record was kept. It is to be observed that no care was taken in selecting the above 111,503 sleepers, and that many thousands of them are said to have progressed so far towards decay that but little prolongation of life could be secured from the preservative treatment. Had all the sleepers been carefully selected the average life would undoubtedly have been found to be considerably longer. The records of the Southern Pacific Railway show a mean life of from eight to nine years for burnettized ties or sleepers.

The *Engineering News* (New York) states that results obtained in the United States show that, by the zinc-chloride or burnettizing treatment, the life of the soft woods is more than doubled, meaning a life of from eight to twelve years for pine that usually lasts from two to five years. This is the mean life, the actual life being from five to over twenty years for treated pine ties or sleepers, against from two to seven for the untreated ones. Creosoting gives from 25 to 50 per cent. more life than the zinc-chloride process, but the cost of the former is three or four times that of the latter, and, moreover, in the case of several woods creosote oil can only be caused to effect a superficial penetration. The injection of from 10 to 15 lb. of creosote oil per cubic foot of wood, according to Mr. Card, gives a life of from twelve to twenty years.

LIFE OF UNTREATED AND TREATED SLEEPERS FROM DATA GIVEN AT THE LEWIS AND CLARKE EXHIBITION, PORTLAND, ORE., 1905.

Species of Sleeper.	Process.	Life. Untreated.	Life. Treated.
		Years.	Years.
Texas Long-leaf Pine . .	Rueping	4 to 6	15 to 20
Texas Short-leaf Pine . .	,,	3 to 5	10 to 15
Texas Loblolly Pine . .	,,	2 to 5	10 to 15
Washington Red Fir. . .	ZnCl.	5 to 6	10 to 12
Mont. Lodgepole Pine . .	,,	4 to 5	10 to 12
Black Hills West-Yellow .	,,	5 to 6	10 to 12
Michigan Hemlock . . .	Wellhouse	5	10
Michigan Tamarack . . .	,,	5	10 to 15
Beech	Creosote	4 to 5	20 to 30
Red Oak	,,	4 to 5	20 to 30

Mr. Batterden (*Proceedings Inst. C.E.*, 1904) states that

about 7 lb. of creosote oil per cubic foot injected into piles at a temperature of 49° C. (120° F.), and at a pressure of 150 lb. per square inch, gave protection against marine worm for eighteen years.

Dr. Herman von Schrenk (American Forestry Congress, 1905) gives the life of red oak or loblolly pine ties or sleepers with zinc chloride treatment as 10 years, with zinc creosote treatment as 16 years, and with creosote treatment as 20 years. According to Mr. J. H. Waterman (American Wood Preservers' Association, 1915), on a section of the Santa Fé line in Western Kansas, ties treated with the zinc chloride process have an average life of from 11 to 12 years, and better results were obtained on an experimental track in the Wyoming district of the Burlington railway. On the C. & E. I. Railroad, between Cypress and Joppa, red oak ties treated by the Wellhouse process are found to have a life of 14 years. The Southern Pacific Railway are said to obtain a 10-year life with ties treated with ½ lb. of zinc chloride per cubic foot. Mr. H. Emerson (American Wood Preservers' Association, 1915), estimates the average life of ties treated with zinc chloride at 8·38 years.

According to a report of the committee on wood block paving, presented at the meeting of the American Wood Preservers' Association held in Chicago, January, 19–21, 1915, where the best methods of treatment, combined with proper selection of materials and methods of laying, are adopted, a life of at least 15 years seems assured for creosoted wood-paving-blocks. From the results of experiments made, the United States Forest Service classify woods used for paving-blocks in the following order of efficiency: (1) Long-leaf pine. (2) White birch. (3) Eastern hemlock, tamarack. (4) Norway pine. (5) Western larch.

Wooden staves for silos subjected to the pressure treatment with coal-tar creosote are said to resist decay for at least 25 to 30 years. The use of a high-grade oil is especially desirable. For the treatment of wooden silos by the pressure process, an oil having a spec. gr. of 1·003 to 1·08 is said to be effective, but for the brush, open tank, and dipping treatments, an oil of a higher spec. gr. is preferable, say of about 1·08 at 60°C. (140°F.). It is estimated by Mr. G. M. Hunt, chemist, Forest Products, Madison, Wis., that about 1,000,000 ft. board measure of green lumber was used in the U.S. for the construction of wooden staves for silos in 1913.

Average Life of Telegraph Poles.

From records by the German Post and Railway Administration. Dr. Frederick Moll.

Untreated poles (mostly oak)	7·7 years
Pine poles, zinc chloride treated (Burnett) . .	12·1 ,,
Pine, copper sulphate treated (Boucherie) . .	13·5 ,,
Pine and spruce, bichloride of mercury treated (Kyan's process)	14·5 ,,
Creosote oil, full-cell process (15 lb. and more per cubic foot of timber)	22·5 ,,

These figures do not, however, give a basis of comparison for the various processes. At the date of writing (1914) nearly all the burnettized poles are removed, while of the "Boucherie" poles about 60 per cent., of the kyanized 50 per cent., and of the creosoted poles 30 per cent. are still sound.

The telegraph administration of the "Reichspostamt" has both watched short-trial lines, and has recorded all poles set since the year 1850. There are at the present time about 7,000,000 poles. Of these nearly 3,000,000 have been removed up to the year 1912.

Investigations by Dr. Moll and of High-Councillor

Novotny (Vienna), based on the German and Austrian statistics, give the following figures:

Untreated poles	7·5	years
Treated with zinc chloride	12·2	,,
,, ,, copper sulphate (Germany)	14·5	,,
,, ,, ,, ,, (Austria)	12·3	,,
,, ,, bichloride of mercury	16·5	,,
,, ,, creosote (15 lb. per cubic foot)	23·0	,,

Mr. De Kermond (*L'Electricien*, Paris) states that official tests have shown that posts treated with copper sulphate have a life of 13 years 9 months; by the Kyan or mercuric-chloride process, nearly 17 years; and by the creosoting process, 19 years 8 months.

A communication from the construction department of the Bavarian State Railways (November, 1909), makes the following statement: " The Bavarian State Railways have been using for a number of years corrosive sublimate (Kyan or mercuric-chloride process) for the preservation of about one-tenth of the ties used, and the results have been good. The average life of the ties in question (pine ties) is, according to the observations made on trial mileages, sixteen years.

The life of wood treated with 4½ oz. of concentrated aczol per cubic foot, according to experience gained during the last five years in continental collieries, is said to be at least 10 years. A stronger impregnation will, it is stated, give a life of from 25 to 30 years. Aczolled sleepers, telegraph posts, etc., are said to have an average life of about 24 years.

CHAPTER XI

Fire-proofing and Fire-retardant Treatment of Wood.

Losses by Fire in Various Countries—Combustion of Wood—Chemicals Rendering Wood Non-inflammable—Tests as to most Practicable Method of Fire-proofing—Various Processes and Chemicals for Rendering Wood Non-inflammable.

Losses by Fire in Various Countries.

THE question of rendering wood non-inflammable or fire-resistant, without weakening it or increasing its tendency to rot, and without being prohibitive owing to the expense attending the process, is an important one, in fact a necessity, if the use of wood is to be continued for building construction. The more populous a country becomes the greater the attention paid to careful and substantial building and to the institution of better fire-protective measures. The following table (see next page) compiled by Mr. Robert E. Prince, of the Forest Products Laboratory, Madison, Wis., from information supplied by the committee on statistics of the National Board of Fire Underwriters, gives the comparative fire loss in sixteen countries during the years 1911 and 1912.

The fire loss shown by the table demonstrates very forcibly the reason why wood is giving place to materials having non-inflammable qualities such as cement, brick, stone, iron, and steel.

It is generally believed that wood is rendered more inflammable by creosoting. It would appear, however,

Names of Countries.	Number of Cities reporting Loss.		Population.		Per capita Loss.	
	1911.	1912.	1911.	1912.	1911.	1912.
United States .	208	300	31,210,084	32,326,633	2·62	2·55
England . .	12	12	9,898,317	7,164,849	·53	·54
France . . .	3	6	3,518,493	4,425,696	·81	·84
Germany . .	8	9	2,306,354	2,659,575	·21	·20
Ireland . . .	2	2	694,292	699,802	·58	·57
Scotland . .	2	2	484,190	485,091	·56	·49
Italy . . .	6	3	1,373,995	282,082	·31	·90
Russia . . .	2	2	3,483,291	3,485,583	1·17	·84
Austria . . .	1	4	2,031,498	2,658,078	·08	·30
Canada . . .	1	5	125,000	957,372	2·61	2·88
Belgium . .	—	1	—	166,445	—	·69
Norway . .	—	1	—	250,000	—	·69
Sweden . .	—	1	—	351,500	—	·13
Switzerland .	—	1	—	140,000	—	·04
The Netherlands	—	2	—	417,693	—	·12
Argentina . .	—	1	—	1,428,042	—	3·58

from a paper by Mr. H. M. Rollins (" Inflammability of Treated Timber ") and also from the opinions expressed during the discussion on this paper (American Wood Preservers' Association, 1910) that it has been found that creosoted railway sleepers and telegraph poles are really less combustible than untreated ones. A part at least of this apparent fire resistance can, according to Mr. Hoxie ("Treated Timber for Factory Construction," American Wood Preservers' Association, 1915) be accounted for by the fact that the sound wood of the preserved material is considerably less combustible than the punky wood of that which has been attacked by fungus. The rapid escape of the heated gases from the immediate neighbourhood of the burning material is also a factor

with fires in the open air. Conditions in mill buildings are, however, quite different. The closed rooms can retain the heat generated by the burning oil, rapidly raising the temperature to the ignition point of the wood, extending the fire and increasing the water and smoke damage to the contents.

The combustion of wood is divided by Mr. R. E. Prince[1] into two parts: "First, the driving off of the volatile gases by heat, and their ignition causing flame. Second, the combustion of the non-volatile portions, analogous to charcoal, causing glow or incandescence, and the production of carbon monoxide, which is a combustible gas. It will readily be seen that the first part of the combustion is the most dangerous. The chief problem, therefore, is to render the volatile gases non-inflammable.

"It has been found that the chemicals most efficient in rendering wood non-inflammable are those that sublime or decompose upon being subjected to intense heat. Non-combustible gases are given off in both cases, which, when mixed with the inflammable gases arising from heated wood, render them non-inflammable.

Experiments were made with the following two classes of chemicals:

(1) Chemicals that "sublime" when subjected to intense heat whose vapours are not inflammable—(*a*) ammonium sulphate, (*b*) ammonium chloride. (2) Chemicals that decompose when subjected to intense heat, giving off non-inflammable gases—(*a*) ammonium phosphate, (*b*) sodium bicarbonate, non-inflammable gas carbon dioxide, (*c*) oxalic acid, non-inflammable gas carbon dioxide.

[1] "Preliminary Work in Fire-proofing Wood," by Robert E. Prince, *Proceedings American Wood Preservers' Association*, 1914.

A method used, says Mr. Prince, in previous fire-proofing work has been to inject chemicals containing large amounts of water of crystallization, the theory being that the water is converted into steam which creates a non-inflammable atmosphere without the wood. Under this method borax and alum were used. Borax also has the advantage of being a fusible salt, thereby protecting the wood fibre with a glossy coating.

The tests were made to ascertain the most practicable method of fire-proofing wood from the standpoint of efficiency of the treatment, for which purpose it is necessary to determine: (1) The efficiency of the treatment in retarding combustion. (2) The minimum amount of a preservative necessary to accomplish the desired results. (3) The corrosive action of the salt used upon the plant equipment. (4) The effect of the treatment upon the strength of the wood. (5) The effect of the treatment upon the painting and finishing qualities of the wood. (6) The corrosive effect of the treatment upon metal coming in contact with the wood, such as nails, screws, hinges, etc.

The following abstracts from Mr. Prince's paper will be of interest: "The method of impregnating the test pieces with fire-proofing material is as follows:

A preliminary treatment is made, using a nearly concentrated solution, to obtain the maximum fire-retarding properties of the salt. Twenty-two pieces of noble fir[1] (*Abies nobilis*), each $1\frac{1}{4}$ by $1\frac{1}{4}$ by 4 inches, are weighed separately and then placed in a container together, with the treating solution which has previously been heated to 66°C. (150·8°F.). The container is then placed in a small treating cylinder and a pressure of 100 lb. per

[1] This wood was chosen on account of its uniformity of grain and texture.

square inch applied by means of compressed air. This pressure is maintained for one-half hour. The pieces are then removed and weighed and the amount of salt absorbed determined. In the case of paints, the pieces are given two coats, allowing plenty of time for both coats to dry before testing.

After treatment the pieces are allowed to season for approximately three weeks. They are then placed in an electrically heated oven at a temperature of 50°C. (122°F.) and dried out to approximately 4 per cent. moisture, when they are removed and allowed to stand until they have reached a constant moisture content (about 6 per cent. in the laboratory). This method is followed in order to obtain uniform moisture conditions in the wood.

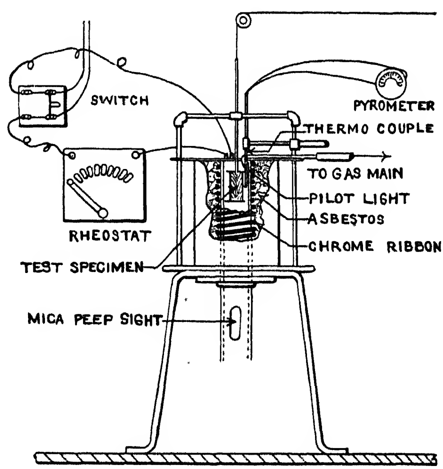


FIG. 113.—Inflammability testing apparatus.

The inflammability apparatus[1] developed at the laboratory (in co-operation with the University of Wisconsin) is shown in fig. 113. This apparatus consists

[1] Numerous methods of testing the inflammability of wood were tried, those published by other investigators being first used. These methods, however, did not give sufficiently accurate comparison of the temperatures at which combustion takes place. And the above method was finally developed.

essentially of a quartz cylinder 3 in. in diameter and 10 in. long, which is wound with a nichrome ribbon having a high electrical resistance. This cylinder is heavily insulated with asbestos and supported in an upright position by an iron frame. A lower chamber about 3.5 in. in diameter and 8 in. deep is attached and opens directly into the quartz cylinder, the two forming, in fact, one continuous chamber. A natural draught is used in making the test. The temperature of the air in the quartz cylinder is determined with an accurately calibrated pyrometer of the thermocouple type, calibrations being made at frequent intervals during the test. A small pilot light is allowed to burn about one inch above the specimen. This is done in order to ignite the inflammable gases as soon as they arise from the heated wood in sufficient volume. It also duplicates the conditions usually existing in a fire.

The method of testing treated wood for fire-retarding qualities is as follows: The test pieces that have previously been dried to approximately 6 per cent. moisture content are placed in an air-tight jar, where they are maintained in a uniform condition until tested. The inflammability apparatus is allowed to heat up until the pyrometer indicator registers approximately 200°C. (360°F.). This temperature is kept constant and a test piece is weighed and then lowered into the hot cylinder, where it is allowed to remain until it ignites, or for forty minutes if ignition does not occur. If the piece ignites the length of time before ignition is recorded by means of a stop-watch. It is then lowered into the cooler chamber and allowed to burn not longer than three minutes.

Notes are taken on the intensity of burning in the following manner:

	Minutes.	Seconds.
Burns violently		
,, freely		
,, poorly		
No combustion		

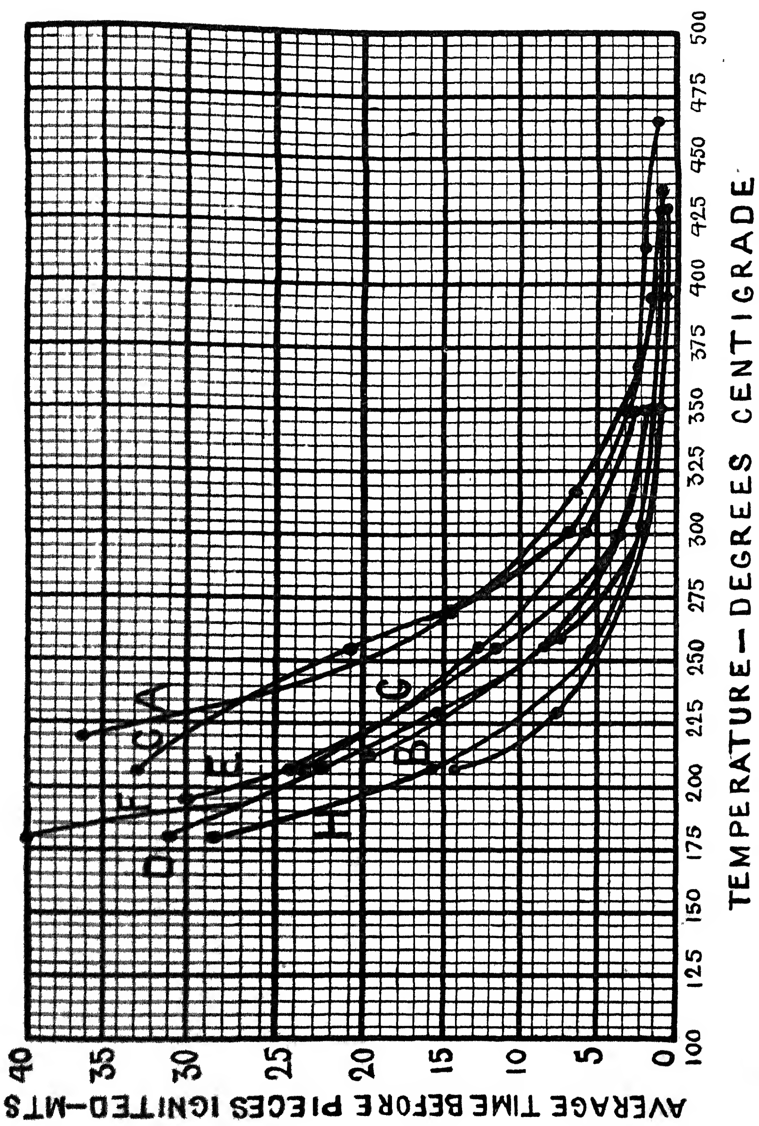
The test is then repeated at other temperatures, each succeeding temperature being approximately 50° higher [1] than the last. The temperatures used generally ranged between 150°C. (302°F.) and 450°C. (842°F.). Enough tests, usually two, are made at each temperature to obtain check results. The results obtained are plotted in a curve with the intervals of time before ignition as ordinates, and ignition temperatures as abscissæ.

In case the preliminary test on concentrated solution of the preservative gives promising results in retarding combustion, other treatments are made with lower strengths of solution until the least concentration practicable has been determined.

The same method was used in determining the relative fire-resisting values of various species of natural wood. Such information is needed both in comparing the various kinds of wood and in judging the effect of treatment. The woods used in this work were representative samples of the material found in structural timbers. Four species were natives of western and five of eastern United States. A comparison of the results obtained on both the western and eastern species are plotted in the form of curves and shown by figs. 114 and 115, and a comparison of the results with untreated and treated woods in figs. 116 and 117.

The following explanatory notes refer to these diagrams, the figures indicating the degrees of temperature at which specimens were held for 40 minutes without ignition.

[1] In a few cases the second temperature was made lower as ignition occurred in a short time.



TEMPERATURE — DEGREES CENTIGRADE
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
AVERAGE TIME BEFORE PIECES IGNITED—MTS
0
5
10
15
20
25
30
35
40
A
B
C
D
E
F
G
H

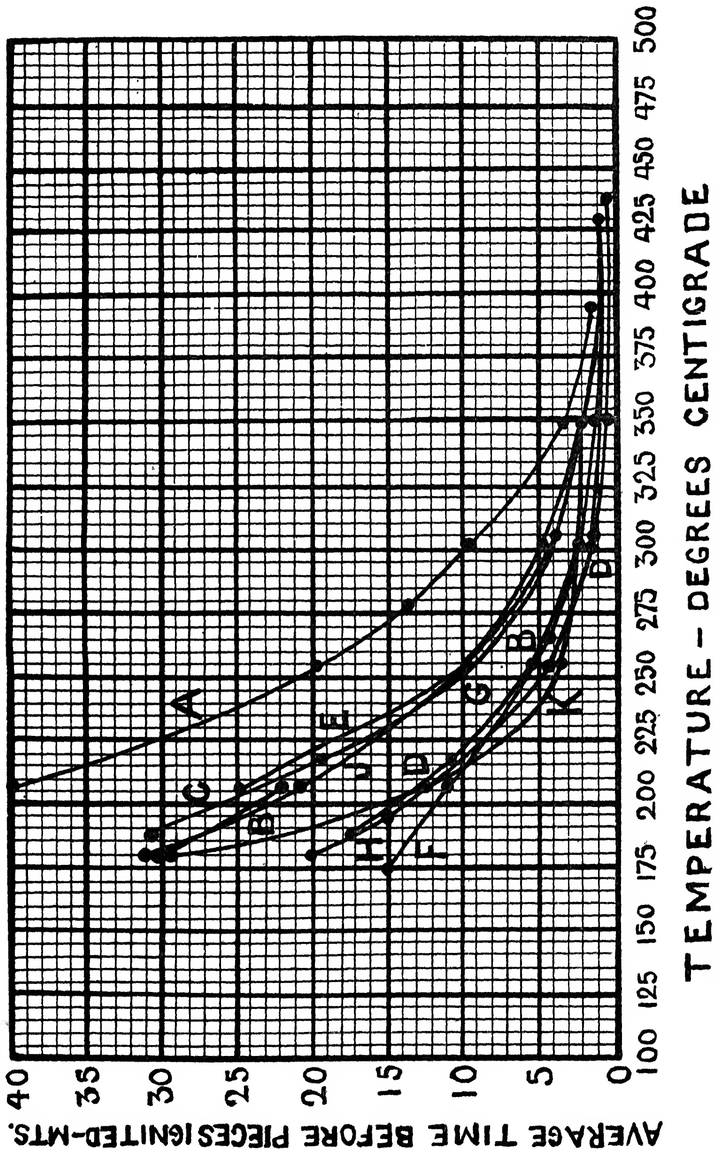


FIG. 115.—Diagram giving time required for various untreated U.S. eastern woods to ignite when subjected to different degrees of heat.

Fig. 114: A, noble fir, air dry, 195; B, do., oven dry, 187; C, western larch, air dry, 180; D, do., oven dry, 157; E, sitka spruce, air dry, 186; F, do., oven dry, 157; G, redwood, air dry, 180; H, do., oven dry, 157. Fig. 115: A, tamarack, air dry, 180; B, do., oven dry, 168; C, basswood, air dry, 168; D, do., oven dry, 168; E, long-leaf pine, air dry, 180; F, do., oven dry, 157; G, red oak, air dry, 157; H, do., oven dry, 157; J, hemlock, air dry, 157; K, do., oven dry, 180. Fig. 116; A, noble fir, natural air dry, 195; B, do., oven dry 197; C, noble fir, treated oxalic acid, 212; D, do., sodium carbonate, 165; E, do., sodium bi-carbonate, 143; F, ammonium chloride, 260; G, borax, 212. The dashed lines show when pieces became incandescent but did not ignite. Fig. 117: A, red oak, air dry, 157; B, do., oven dry, 157; C, red oak, commercially treated with ammonium phosphate and sulphate, 260. The dashed line shows when pieces became incandescent but did not ignite.

Of the western woods tested, western larch (*Laris occidentalis*) and noble fir (*Abies nobilis*), fig. 114, withstood the action of the various degrees of heat used in the test without igniting longer than red wood (*Sequoia sempervirens*) or sitka spruce (*Picea sitchensis*). The moisture contents of the air-dry pieces at the time they were tested were as follows:

Kind of Wood.	Average per cent. Moisture in Piece at time of Testing.
Western Larch	19·5
Noble Fir	18·0
Redwood	19·4
Sitka Spruce	19·1

The oven-dry pieces, of course, contained no moisture. The relative positions of the air-dry and oven-dry in-

flammability curves show the fire-retarding effect of moisture in the wood upon the ignition temperature.

The results obtained on the eastern woods (fig. 115) show that tamarack (*Larix laricina*) withstood the action of the heat longer than red oak (*Quercus rubra*), eastern hemlock (*Tsuga canadensis*), basswood (*Tilia Americana*), and long-leaf pine (*Pinus palustris*).

The moisture contents of air-dry pieces at time of test were as follows :

Kind of Wood.	Average per cent. Moisture in Piece at time of Testing.
Tamarack	15·0
Red Oak	11·2
Eastern Hemlock	18·5
Basswood	9·8
Long-leaf Pine	*

* The moisture contents of the long-leaf pine pieces tested could not be determined due to the volatilization of the resinous material changing the loss in weight. Oven-drying long-leaf pine appears to lower the ignition temperature (*see* fig. 115).

The average per cent. loss in weight of each species due to burning was calculated from all the pieces in the test. The results are given in the following table :

	Per cent. Loss to Weight.	
	Oven dry.	Air-dry.
Western Woods :		
Sitka Spruce	25·6	34·2
Larch	38·8	35·0
Redwood	23·2	37·0
Noble Fir	38·8	21·0
Eastern Woods :		
Long-leaf Pine	16·7	16·0
Tamarack	22·4	20·28
Basswood	48·6	36·0
Red Oak	39·0	29·5
Hemlock	30·0	30·5

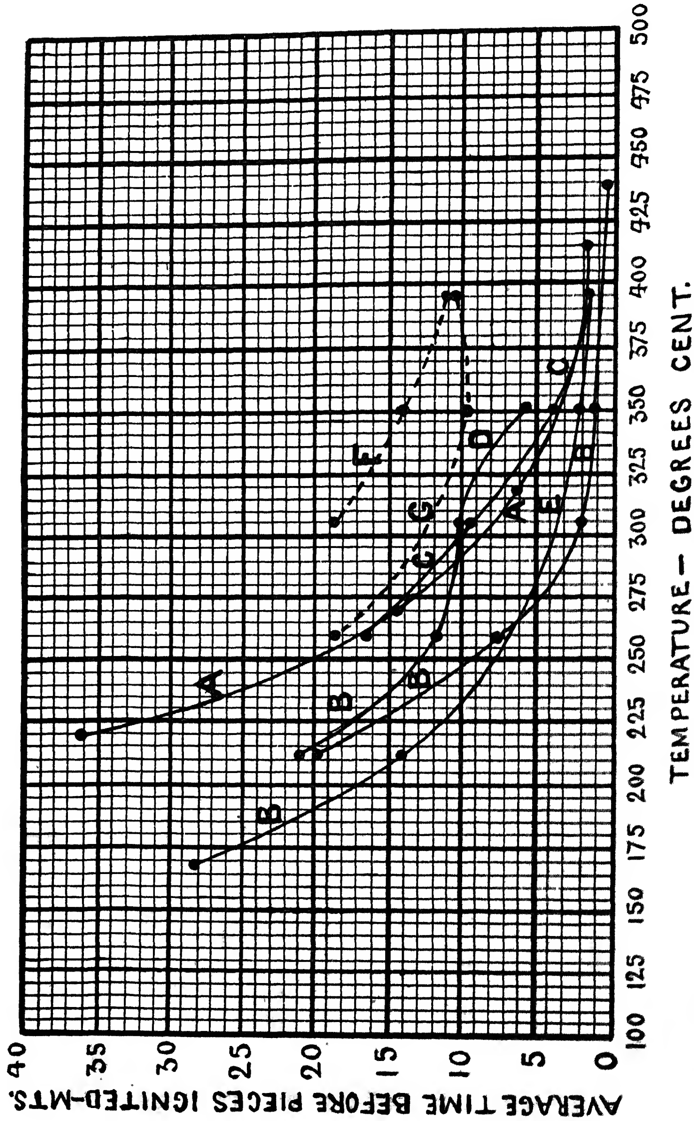


FIG. 116.—Diagram giving comparison of results obtained with treated and untreated noble fir when subjected to various degrees of heat.

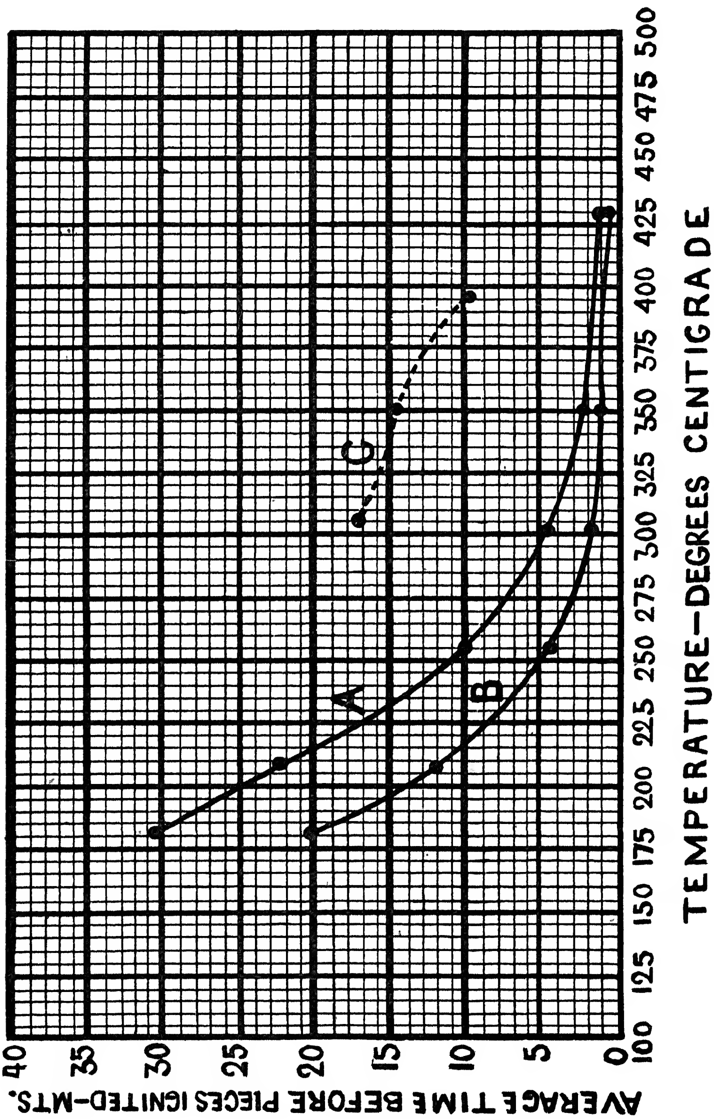


FIG. 117.—Diagram giving comparison of results obtained with treated and untreated red oak when subjected to various degrees of heat.

This per cent. loss in weight data can be used as a measure of the tendency of the pieces to burn, once they are ignited: that is, if the wood tested is a good conductor of heat, the piece will be heated up throughout the entire block, and will be in a better condition to burn than a piece that is a poor conductor and has not allowed the heat to penetrate so far into the wood. The results show that with the exception of long-leaf pine,[1] tamarack and red wood were the two poorest conductors of heat as they lost the least weight in burning. A summary of the results obtained shows that of the eight species tested tamarack is the most fire-resistant, while redwood comes next, even though western larch and noble fir were slower to ignite than redwood. Up to the time of writing the paper fire-proofing tests have been made at the laboratory on noble fir, using the following fire-retarding agents:

Strength of Solution.	Amount of dry salt injected per cubic foot of wood.
33 per cent. solution sodium carbonate . . .	11 lb.
35 ,, ,, ,, ,, bicarbonate . .	11 ,,
30 ,, ,, ,, oxalic acid	10 ,,
20 ,, ,, ,, borax	5 ,,
20 ,, ,, ,, ammonium chloride . .	5½ ,,

Commercially fire-proofed red oak with a mixture of ammonium sulphate and ammonium phosphate was also tested.

[1] This small loss in weight is due to the resinous material found in long-leaf pine having a lower ignition temperature than the other volatile portions of the wood. In other words, the resinous materials were using the wood substance as a wick, and as there was a large amount of this material in the long-leaf pine, combustion was supported principally by the resin during the three-minute period that the wood was allowed to burn.

The results of these tests as compared with untreated wood are shown in figs. 116 and 117.

Sodium carbonate did not prove efficient in retarding combustion (fig. 116). It also caused a marked weakening of the wood.

Sodium bicarbonate did not prove efficient in retarding combustion (fig. 116), and also caused a marked weakening of the wood.

Oxalic acid did not prove efficient in retarding combustion (fig. 116), and also caused a marked weakening of the wood.

Borax was of considerable value in retarding combustion (fig. 116). The dotted curve G, fig. 116, shows the comparison with natural wood and the other fire-proofing agents used. The points determining the position of this curve were obtained after the piece had become charred and incandescent. A small amount of an inflammable gas, probably carbon monoxide, was generated which burned with a small blue flame on the top of the test specimen, but only with the aid of the pilot light.

Ammonium chloride proved of considerable value in retarding combustion (fig. 116). The points determining the position of the dotted curve F, fig. 116, represent the same condition as was described under borax. However, ammonium chloride is somewhat hygroscopic, and its use may be restricted for this reason.

A number of tests were made on pieces of red oak, treated by a commercial fire-proofing company with a solution containing ammonium phosphate and ammonium sulphate. The strength of the solution was not known. Ammonium phosphate and ammonium sulphate proved of considerable value in retarding combustion (fig. 117). The points constituting the dotted curve C,

fig. 117, represents the same condition as was found in ammonium chloride and borax.

A summary of the results obtained show the following: (1) Ammonium salts are of considerable value in fire-proofing wood. It was impossible to ignite the wood, under the conditions of test, that had been treated with these salts. (2) Borax is of considerable value in fire-proofing wood. It has not the value of ammonium salts, but promises a means of lessening the cost of treating by using it with another salt of greater value. (3) From the good results already obtained it appears possible to devise a reasonably inexpensive method of rendering wood fire-resisting.

Other processes and chemicals that have been claimed to render wood either uninflammable or to have powerful fire-retardant properties are the following: Silicate of potash or soluble glass. Alum and borax mixed in equal parts (biborate of soda); the effect of impregnating with alum is to both weaken the wood and to greatly increase its tendency to decay. Chloride of sodium, deprived of any magnesian salts which it contains, has been tried, but unsuccessfully. Double salt of manganese and zinc. Strong solution of potash, baryta, lime, strontia or any of their salts first forced into the wood, and, after draining, hydro-fluo-silicic acid is forced in, forming an insoluble compound which it is claimed is capable of rendering the wood uninflammable. Chloride of calcium. Chloride of zinc is also said to possess fire-resisting qualities. Silicate of soda in solution and applied like paint, two or three coats, forms a hard surface which is very durable and affords a considerable amount of protection against fire. Another fire-resisting paint consists of 1 part of arsenic, 6 lb. of alum, 10 parts of potash, diluted with 320 parts of water, all by weight,

and mixed with oil or tarry matters to form a suitable consistency.

A fire-proofing process called "Oxylene" introduced by The Timber Fire-proofing Company, Ltd., London, is claimed by the proprietors to render timber incapable of being set alight and consequently of spreading flame, and, moreover, they state that wood treated in this manner does not corrode nails or screws, does not spoil paint or polish, does not warp, does not deteriorate, and is unaffected by atmospheric conditions.

The chemicals employed are non-volatile, perfectly stable and without detrimental action upon the wood or metals brought in contact with it. The fire-proof and non-inflammable character imparted to the wood is claimed by the inventor to be permanent and unaffected by time, and the life of both hard and soft wood to be increased by the treatment. Even when treated wood is exposed to the action of the weather or water for prolonged periods its fire-resisting qualities are not diminished to any appreciable extent.

The impregnating solution employed, which is patented (Arthur William Baxter, No. 5209 of 1905), is obtained by dissolving phosphate of ammonia with boracic acid in water, the phosphate of ammonia not exceeding 15 per cent. by weight and the boracic acid not exceeding 1·5 per cent. by weight. The solution preferably employed is in the proportions of 12 parts of phosphate of ammonia and 1 part of boracic acid to 87 parts of water.

The process is carried out as follows: The wood to be treated is placed in the closed cylinder or retort shown on the right-hand side in fig. 118 (which view shows a portion of the interior of the works), and is therein subjected to a steaming and vacuum treatment, by

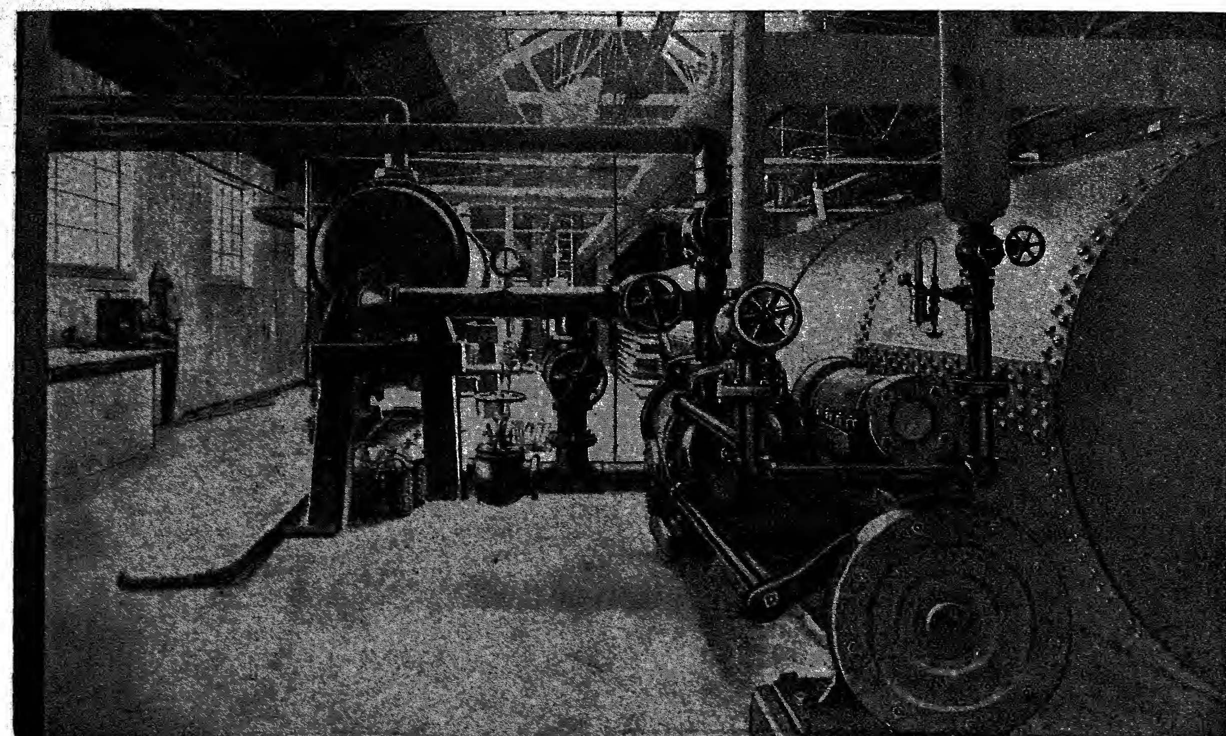


FIG. 118.—The Timber Fireproofing Company, Ltd., "Oxylene" process. View showing the interior of works.

which the air and moisture in the pores of the wood are removed and the sap water vaporized. The charge of wood is then impregnated under hydraulic pressure with the solution of antipyrine chemicals, which replace the elements driven out by the preliminary treatment. The water of the solution is finally dried off, the chemicals in minute crystal form remaining permanently embedded in the fibres. Fig. 119 is a view of the company's works showing wood stacked for drying after treatment.

The effect of the treatment is said to be that when heat is applied to the wood the crystals in the wood expand and form a glassy coating which excludes the oxygen in the air and prevents its combination with the wood, thus rendering flame an impossibility. The greater the heat to which the treated wood is subjected the more these crystals expand, and though in time the chemical action of each crystal becomes exhausted and the wood becomes charred, fresh crystals at once take their place, so that even though the wood may become eventually charred completely through, no flame will be generated.

As showing the efficiency of this process the makers give the following extract from a Board of Trade official report on an accident which took place on the District Railway at Sloane Square Station on the 8th January, 1908, on a District Railway train the woodwork of which had been fire-proofed by the company: ". . . Below the floor level, the metal pipe carrying the electric-lighting wires and a metal junction box were fused. The under-side of the timber flooring, immediately above this pipe and junction box, were charred in places. The charring nowhere exceeded a quarter of an inch in depth. No mark of fire could be found inside car on the flooring, seats, or sides."

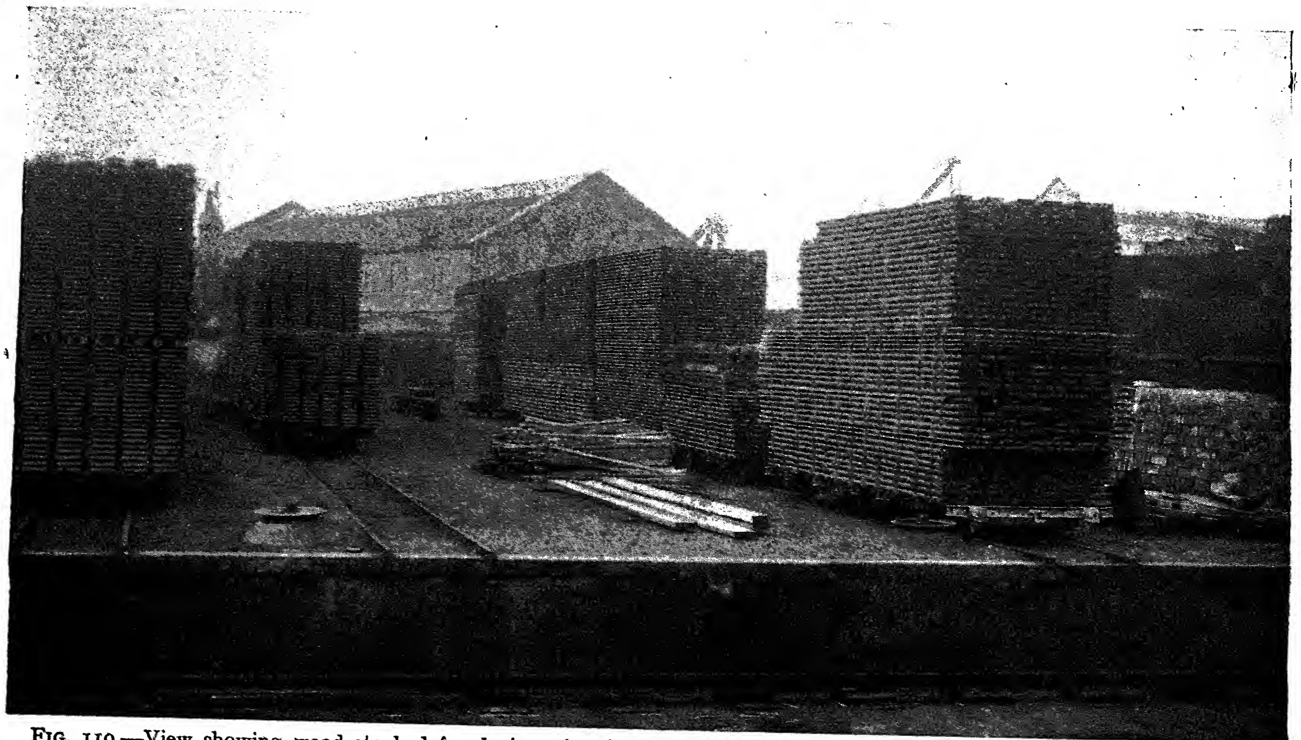


FIG. 119.—View showing wood stacked for drying after having been subjected to the "Oxylene" fire-proofing treatment.

A solid deal door $1\frac{7}{8}$ in. in thickness treated by the "Oxylene" process was recently tested by the British Fire Prevention Committee, with the result that a fire rising to a temperature of 1680°F. playing upon it for one hour could not cause it to flame at any point, and only succeeded in charring it to a depth of $\frac{3}{4}$ of an inch.

The writer has also himself carried out some experiments on a small scale with wood treated by this process, and found it impossible to ignite same under the action of a fierce flame, the material charring without giving off flame. Further experiments made with a view to ascertaining the value of the treatment as a preventative to decay have so far proved satisfactory. Attempts to force the growth of dry-rot bacillus on a sample of treated wood proved abortive, and the sample after having been suspended in a cesspool for four months, and afterwards placed in an exposed position for about eight months, has exhibited no signs of decay.

A fire-proofing process suggested many years ago by Payne consists in steeping the wood in a solution of barium or calcium. Professor Fuchs, of Munich, about the same time recommends the application of the following solution, which forms a vitreous coating: Composition of potassa or soda 10 parts, siliceous earth 15 parts, charcoal 1 part, fused and formed into a water glass and applied in solution. Another old composition consists of fine sand 1 part, wood ashes 2 parts, slaked lime 3 parts. These ingredients having been ground in oil to be laid on in two coats with an ordinary painter's brush, the first coat thin and the second thick. These two latter are strictly speaking fire-retardant coatings, and do not render the wood non-inflammable.

A report presented to the National Fire Protection

Association at Chicago (*Engineering News*, New York, 1901) divides the subject into two parts: Fire-proofed wood, that is to say wood chemically treated so as to render it practically non-inflammable throughout; fire-retardant coatings for wood such as paints, etc.

As regards the first of these, only three processes for fire-proofing wood throughout were stated to be at that time in practical use in America. The oldest of these processes, known as the Bachert process, has been in use since 1895, at which time wood, prepared by this process, was first supplied for war vessels to the Government of the United States, and since that time most of the war vessels and many large buildings have been fitted with wood treated in this manner prepared by the Electric Fire-proofing Company. The process consists in first exposing the wood to steam under light pressure, then subjecting it to a vacuum, and finally impregnating it with certain chemicals under a high pressure. The second process used by the American Wood Fire-proofing Company is conducted in a practically similar manner.

In the third process, known as the Ferrel process, neither steaming nor vacuum is used, the wood being only impregnated by chemicals under very high pressure. In all cases the wood is subsequently kiln-dried, when it is found to weigh about 10 per cent. more than before the treatment.

The transverse strength of white pine is found to be increased, and that of yellow pine to be diminished, the compression strength being diminished in both cases, whilst the tensile strength is increased. The New York Building Department accepts wood treated by the Bachert process, the effect of which seems to be permanent. Timbers up to 12 in. by 12 in. can be successfully treated, the cost increasing greatly with the size, and

being in any case almost prohibitive for general use. The treated wood is somewhat more difficult to work than ordinary wood, and takes a good finish.

There are numerous fire-retardant coatings in market, several of which appear to be fairly efficacious.

A paint or coating that is said to have been used with some success for this purpose consists of 3 parts of alum, 1 part of sulphate of copper or green vitriol and pipeclay. Form a strong solution of alum with hot water, and a weak solution of green vitriol mixed with pipeclay to the consistency of ordinary paint. Apply two coats of the first solution to the wood and allow it to dry, then give one coat of the latter.

A process designed to render timber uninflammable and also to rapidly season timber, invented by Gardner, takes from four to fourteen days, in accordance with the dimensions of the material. The process consists, briefly, in dissolving the sap by means of chemicals in an open tank and driving out the remaining moisture, leaving the fibre only. A further injection of chemicals is then made by means of which the durability of the wood is claimed to be increased, and it is rendered uninflammable. This process is stated to have been found to act most satisfactorily in the case of sleepers, mine props, logs of mahogany for cabinet work, and smaller scantlings of fir and pine. Experiments are said to have demonstrated that the sap of the wood was removed, the resistance of treated wood to crushing raised from 40 to 90 per cent., and its density greatly increased.

CHAPTER XII

Cost of Preservative Treatment.

Creosoting—Burnettizing—Kyanizing—Powellizing—Aczollizing—Fire-proofing—Etc.

THE cost of pickling or treating wood varies considerably, according to the wood being treated, the process employed, and the country, or even the district, where the work is being carried out, etc.

The cost of creosoting in this country on the pressure system varies from 3*d.* to 5*d.* per cubic foot, in accordance with the price of the oil and the amount injected. For estate work the amount of oil used for impregnation is generally about ·75 gallon per cubic foot, and the labour of attending to the working of such a creosoting plant may be calculated at ·5*d.* per cubic foot. Taking the price of creosote oil at 4*d.* per gallon, the cost of treatment works out at 3·5*d.* per cubic foot. Creosoting timber for railway purposes costs for pine and fir from 2·9*d.* to 5·1*d.* per cubic foot.

In India the cost of impregnating railway sleepers is given as 1*s.* for 3 lb., 2*s.* for 6 lb., and 3*s.* for 10 lb., impregnation per cubic foot, with creosote oil at 7 annas (10½*d.*) per gallon.

In France creosoting on the Paris-Lyons-Mediterranean Railway is given by Mr. Herzenstein (*Bulletin of the International Railway Congress*, 1901) as for oak 1·6*d.* per cubic foot, for fir 5·4*d.* per cubic foot. On the Northern Railway, with the Blythe creosoting process,

1·8*d*. per cubic foot for oak, and 3·5*d*. per cubic foot for fir. A writer in the *Revue Générale des Chemins de Fer* gives the average cost of creosoting on French railways as being, for oak 8·6*d*., and for beech or pine from 1*s*. 3·5*d*. to 1*s*. 9·3*d*. per sleeper, according to the amount of oil injected.

In the United States, from information compiled by Mr. J. D. Isaacs, Permanent Way Engineer to the Southern Pacific Railway, it appears that at Oakland, Cal., and Latham, Ore., the amount of creosote oil injected is from 1·12 gallon to 1·18 gallon per cubic foot, or on an average about 10 lb. per cubic foot, and the average cost (including price of oil, fuel, labour, maintenance, oil waste, and water) is 15·96 cents, or about 8*d*. per cubic foot. The average tie or sleeper used in the United States contains 3·5 cubic feet. The cost of treating the best woods for paving-blocks with 16 lb. of oil per cubic foot is 16 cents (8*d*.) per cubic foot. On the authority of Mr. Rowe, for the full creosote process, with an injection of 15 lb. of oil per cubic foot, a 3 cubic foot tie or sleeper would cost 38·36 cents (19·18*d*.), and a 3·75 cubic foot tie or sleeper 47·95 cents (23·97*d*.). This works out at 12·78 cents (6·39*d*.) per cubic foot, and 12·52 cents (6·26*d*.) per cubic foot.

The cost of steaming in the U.S. is given by the American Wood Preservers' Association as being 60 cents per 1,000 feet B.M., overhead charges not included, for boards, planks, and smaller sizes; 50 cents to 90 cents for lumber and large timbers; ¼ cent to 3 cents each for cross ties; 1 cent each for cross ties containing approximately 3 cubic feet of wood. These estimates do not include overhead charges, and the cost of fuel is taken at 2 dollars per ton delivered at the works.

The Allis-Chalmers Company, Milwaukee, Wis., give the following as the approximate cost of treating sleepers, exclusive of royalties, by the seven most-used preservative processes, the average size of hewn ties or sleepers being 7 in. × 9 in. × 8 ft. = 3·45 cubic feet, or 3·5 cubic feet for sawn ties of same dimensions.

APPROXIMATE COST OF TREATING SLEEPERS, EXCLUSIVE OF ROYALTY (Allis-Chalmers Co.)

(1) Burnettizing or zinc-chloride process (about ½ lb. of dry zinc per cubic foot . . .	$0·12	(6*d.*)	per sleeper
(2) Wellhouse or zinc-tannin process (½ lb. of dry zinc plus glue and tannin per cubic foot)	$0·16	(8*d.*)	,,
(3) Card, Rutger or zinc-creosote process (1½ lb. of creosote oil and 1 lb. of dry zinc per cubic foot)	$0·18	(9*d.*)	,,
(4) Rueping, partial cell process (about 6 lb. of creosote oil per cubic foot)	$0·225	(11*d.*)	,,
(5) Lowry, partial cell process (6 lb. of creosote oil per cubic foot)	$0·225	(11*d.*)	,,
(6) Absorption or open-tank process (about 6 lb. of creosote oil per cubic foot) . . .	$0·230	(11·5*d.*)	,,
(7) Full-cell creosote process (about 10 lb. of creosote oil per cubic foot).	$0·335	(16·5*d.*)	,,

COST OF TREATING SLEEPERS FROM DATA GIVEN AT THE LEWIS AND CLARKE EXHIBITION, PORTLAND, ORE., 1905.

Species of Tie.	Process.	Amount of Preservative.	Cost of Treatment.
Texas Long-leaf Pine	Rueping	16 lb. creosote per sleeper	16 cents (8*d.*)
Texas Short-leaf Pine	Rueping	16 lb. creosote per sleeper	16 cents (8*d.*)
Texas Loblolly Pine	Rueping	16 lb. creosote per sleeper	16 cents (8*d.*)
Washington Red Fir	ZnCl.	½ lb. creosote per cubic ft.	10 cents (5*d.*)
Mont. Lodgepole Pine	ZnCl.	½ lb. creosote per cubic foot	10 cents (5*d.*)
Black Hills West Yellow	ZnCl.	½ lb. creosote per cubic foot	10 cents (5*d.*)
Michigan Hemlock	Wellhouse	½ lb. creosote per cubic foot	12 cents (6*d.*)
Michigan Tamarack	Wellhouse	½ lb. creosote per cubic foot	12 cents (6*d.*)
Beech . . .	Creosoted	56 lb. creosote per sleeper	60 cents (2*s.* 6*d.*)
Red Oak . .	Creosoted	25 lb. creosote per sleeper	30 cents (1*s.* 3*d.*)

Messrs. Harrington, Emerson and T. T. Bower [1] give the following formula for ascertaining the annual maintenance cost of a tie, viz.:

$$A - \frac{C}{Y} + C(i+t)$$

Where :

A = Annual maintenance charge.

C = First cost of tie in track.

[1] "A Method for Finding the Annual Charges for Ties." (American Wood Preservers' Association, 1915.)

Y = Average year's life determined by number of removals.

i = Rate of interest on investment.

t = Tax rate on investment.

A good tie, according to the above authorities, costs at least \$1·30, and unless treated wears out in 7 years. Annual cost, \$0·213. At this rate it would cost a road with 25 million ties 4 million dollars a year more than it did 20 years ago. Creosote, at a cost of \$0·25, put on heavy tie plates at a cost of \$0·35 more, and the first cost rises to \$1·60. Such a tie would have to last 16 years to give a yearly cost of \$0·213. Assuming, however, a life of 10 years, the annual cost becomes \$0·273. This is \$5,500,000 a year more than it was about 1905.

In 1912 Mr. Emerson says that the cost of ties per locomotive mile was \$0·032, and an addition of 1 per cent. taxes on cost of ties in track would bring the above figures to \$0·078. It costs, therefore, about as much to maintain ties per locomotive mile as to maintain the locomotives themselves. The cost is rising, and may be now put at from \$0·05 to \$0·30 a year for maintenance. The problem is therefore, he observes, one of growing importance in the United States.

F. J. Angier[1] gives the cost of treated sill ties, i.e., ties upon which to place ties stacked for seasoning, as \$0·58 (\$0·40 cost of ties each, \$0·18 cost of treating and laying). Annual cost per sill, \$0·0696, made up as follows: Interest and taxes (6 per cent. plus 1 per cent.), \$0·0406; renewal cost assuming a life of 20 years, \$0·0290.

[1] "Sill Ties." (*Proceedings American Wood Preservers' Association*, 1915.)

TABLE SHOWING COST OF TREATMENT, ANNUAL CHARGES, ETC.
Dr. Herman von Schrenk (American Forestry Congress, 1905.)

Timber and Treatment.	Length of Service.	Original Cost.	Cost of Treatment	Annual Charge.
White Oak, untreated .	10 years	\$0·85	—	\$0·121
Red Oak or Loblolly Pine, untreated	5 ,,	·40	—	·124
Red Oak or Loblolly Pine, with zinc chloride treatment	10 ,,	·40	\$0·16	·085
Red Oak or Loblolly Pine, with zinc creosote treatment	16 ,,	·40	·25	·065
Red Oak or Loblolly Pine, with creosote treatment	20 ,,	·40	·45	·069

The following table gives the approximate cost of treating wood paving-blocks, 3·5 in. and 4 in. deep, cut from timber 3 in. × 6 in., 3 in. × 8 in., 3 in. × 10 in., 4 in. × 6 in., or 4 in. × 10 in. Seasoned blocks, weighing about 20 lb. per cubic foot. Cost based on creosote oil at \$0·07 (3·5*d.*) per gallon, and balance of treatment \$0·02 (1*d.*) per cubic foot.

Amount of creosote oil injected per cubic foot in lbs.	Depth of block in inches.	Cubic feet per superficial square yard.	Creosote oil injected per sup. sq. yard in lbs.	Weight per sup. sq. yard after treatment in lbs.	Approximate cost of treatment per sup. sq. yard.
16	3·5	2·63	42·08	147·28	19·5 *d.*
	4	3	48	168	22·5 ,,
18	3·5	2·63	47·34	152·43	22 ,,
	4	3	54	194	25 ,,
20	3·5	2·63	52·6	157·8	24 ,,
	4	3	60	200	27 ,,

The first cost of creosoted wood block pavement is given in the Report of the Committee on Wood Block Paving (American Wood Preservers' Association, Annual Meeting, January 19–21, 1915) as averaging from 2·25 dollars to 3·75 dollars per square yard, the price depending to a large extent upon the locality, species of wood used, method of treatment, amount laid, thickness of foundation and various other factors. In recent practice the width of blocks has often been reduced to 3 inches.

The cost of treating wooden silos is given by Mr. Geo. M. Hunt,[1] chemist in Forest Products, as follows: By the brush treatment a silo containing 3,000 board feet, and absorbing about 30 gallons of creosote at 20 cents (10*d.*) per gallon, would cost \$6·00 (25*s.*), and the labour at \$2·00 per day would probably amount to about \$6·00 (25*s.*), making the total cost of treatment \$12·00 (50*s.*). The cost of giving the bottom of the staves an open-tank treatment and the remainder a brush treatment would be for a silo containing 3,000 board feet about as follows: 42 gallons of creosote at 20 cents (10*d.*), per gallon, \$8·40 (35*s.*); 3 days' labour at \$2·00 (8*s.* 4*d.*) per day, \$6·00 (25*s.*); total, \$14·40 (60*s.*).

The cost of treating piles is said to be \$0·10 per cubic foot, with 10 lb. of oil per cubic foot, each additional lb. of oil costing an additional cent. Piles range from 8 in. to 20 in. in diameter, and from 10 ft. to 90 ft. in length, the average sizes running about as follows: 10 in. to 14 in. diameter, by 28 ft. in length; 11 in. to 15 in. diameter, by 40 ft. in length; 8 in. to 18 in. diameter, by 60 ft. in length; 8 in. to 20 in. diameter, by 90 ft. in length. Green piles weigh about 55 lb. per cubic foot, and seasoned or steamed piles, about 40 lb. per cubic foot.

[1] *The American Lumberman*, March 13, 1915.

The average treatment of piles in the United States is from 10 lb. to 20 lb. of creosote oil per cubic foot.

The cost of creosoting timber with 10 lb. of creosote oil per cubic foot is about \$8·00 per thousand board feet, and for each additional pound of creosote oil used \$0·75 must be added; creosote oil being taken at \$0·07 per gallon.

The cost of the chloride of zinc or burnettizing process for timber, with ½ lb. of dry zinc-chloride per cubic foot, is about \$3·00 per 1,000 board feet. Treatment with "burnettizine" costs about the same as creosoting, viz., 5*d.* per cubic foot.

The price of corrosive sublimate used in the kyanizing process has, combined with the slowness of the process, caused it to fall into disuse here, and, at the present time, the United States and Germany are about the only places where it is still used to some extent in certain localities, probably owing to there being a difficulty in obtaining chloride of zinc and oil of creosote. In this country the price of corrosive sublimate is such as to render its use as a preservative agent impossible, with creosote oil in the neighbourhood of 4*d.* per gallon, and pure zinc-chloride at 2*d.* per lb.

The cost of treating sleepers on the chloride of zinc process has been found by the Southern Pacific Railway Company to average, with two of their portable plants, 8·20 cents (4·1*d.*) and 7·41 cents (3·7*d.*) per tie or sleeper, or 2·5 cents (1·25*d.*) per cubic foot.

The zinc-tannin or Wellhouse process is considerably more expensive, the actual cost at four of the standard works in the United States is given by Mr. Rowe as being, for a 3 cubic feet sleeper, 7·81 cents (3·9*d.*) for chemicals, and 4·61 cents (2·3*d.*) for labour, or a total

of 12·42 cents (6·21*d.*) per sleeper. According to this the cost per cubic foot is slightly over 4 cents (2*d.*).

The Rueping partial-cell process, with an impregnation of 5 lb. of creosote oil per cubic foot, and taking the oil at 4*d.* per gallon, costs about 2·75*d.* per cubic foot.

The cost of the zinc-creosote process (Rutger and Card) would be about 3·25*d.* per cubic foot, the higher cost being due to the zinc-chloride required per cubic foot in addition to the creosote oil.

The cost of preserving by the Crésol-calcium process is stated to be as follows: in England, ·47*d.*; in Sweden, ·5*d.*; and in India, ·6*d.* per cubic foot.

The cost of treating wood with naphthalene, the price of the latter being about 60*s.* per ton delivered, is about the same as for creosoting. Although the material is cheaper than creosote, large quantities are taken up by most woods.

The cost of the saccharine or powellizing process is given as being in Bombay 5 annas (7·5*d.*) per cubic foot, and in Western Australia 3·68*d.* per cubic foot, plus the royalty to the patentees. Where sugar is very cheap the cost, exclusive of royalties, would, according to Mr. Ryan, be 1·36*d.* per cubic foot.

The aczol process, when employed for the preservation of wood intended to be used for ordinary purposes, costs about 5*d.* per cubic foot. For the preservation of timber used in collieries, as pit-props, etc., and of other wood especially exposed to the attack of rot and treated with 4½ oz. of concentrated aczol per cubic foot, the total cost of the injection is given as 1¼*d.* per cubic foot.

The following is the approximate average cost of impregnation with fifteen different antiseptics, including processing, from various sources:

Process.	Cost per cubic ft.
(1) Atlas (10 per cent. sol.)	3*d.*
(2) Béllit	1·75*d.*
(3) Carbolineum	1·5 to 3·8*d.*
(4) Chloride of zinc	·72 to ·94*d.*
(5) Chloride of mercury	8*d.*
(6) Crésol-calcium	·46 to ·6*d.*
(7) Crésoyle	3*d.*
(8) Green oil	1·9 to 4*d.*
(9) Jodelite	4·9 to 7*d.*
(10) Microsol	3 to 4*d.*
(11) Rueping	1·2*d.*
(12) Saccharine solution	1·36 to 7·5*d.*
(13) Solignum	4·2*d.*
(14) Sulphate of copper	5·2*d.*
(15) Vulcanizing	2·5 to 4*d.*

The cost of fire-proofing wood by the "Oxylene" process is given by the Timber Fire-proofing Co., Ltd., Fulham, London, the proprietors of the system, as 3*s.* 6*d.* per cubic foot for oak or teak, and 3*s.* per cubic foot for all other kinds of wood. The above prices are based on the assumption that an order of at least 300 cubic feet will be placed at one time.

The cost of seasoning or drying wood by the vapour process when live steam is used is given as 6*d.* per 1,000 ft. of timber, the price of coal being taken at 13*s.* 6*d.* per ton, no account being taken of interest on the initial outlay of the kiln structure, etc., nor of other standing charges. Where exhaust or waste steam is available the fuel bill is reduced to practically a nominal amount.

The approximate cost of complete timber-preserving plants of various capacities will be found given in the table on the folding plate facing the preceding page.

Useful Formulæ, Tables, Memoranda, etc.

EXTRACTS FROM TYPICAL CREOSOTE OIL SPECIFICATIONS

W. C. Mitchell, M.Sc., Forestry Branch, Canada.

City of Toronto, Canada West.

(1) Preservative. The preservative to be used shall be a product of coal-gas, water-gas, or coke-oven tar, which shall be free from all adulteration, and contain no raw or unfiltered tars, petroleum compounds, or tar products obtained from processes other than those stated.

(2) The specific gravity shall be not less than one and ten-hundredths (1·10) nor more than one and fourteen-hundredths (1·14) at a temperature of thirty-eight (38) degrees Centigrade.

(3) Not more than three and one-half ($3\frac{1}{2}$) per cent. shall be insoluble by continuous hot extraction with benzol and chloroform.

(4) On distillation, which shall be made exactly as described in Bulletin No. 65 of the American Railway Engineering and Maintenance of Way Association, the distillate, based on water-free oil, shall not exceed one-half ($\frac{1}{2}$) of one (1) per cent., at one hundred and fifty (150) degrees Centigrade, and shall not be less than thirty (30) per cent. nor more than forty (40) per cent. at three hundred and fifteen (315) degrees Centigrade.

(5) The oil shall contain not more than three (3) per cent. of water.

City of Minneapolis, United States.

The preservative to be used shall be a product of coal-gas, water-gas or coke-oven tar, which shall be free from all adulter-

ations and contain no raw or unfiltered tars, petroleum compounds or tar products obtained from processes other than those stated.

(*a*) The specific gravity of the oil shall be at least 1·10 at a temperature of 38 degrees Centigrade.

(*b*) It shall be completely liquid at 35 degrees Centigrade and show no desposit on cooling to 22 degrees Centigrade.

(*c*) It shall not contain more than 3 per cent. of matter insoluble by hot continuous extraction with benzol and chloroform.

(*d*) It shall be subjected to a distillation test as specified below, and shall conform to the following requirements: 100 grams of oil shall be placed in an 8-oz. retort, fitted with a thermometer, the bottom of the bulb of which shall be placed one-half inch above the oil and not moved during the test. The discharge opening of the retort shall be from 20 to 24 inches from the bulb of the thermometer and the retort shall be covered to prevent too rapid radiation. The percentages are for dry oil and by weight. The average of a number of tests shall show a mean of these percentages, viz.:

Up to	150	degrees C.,	nothing must come off.
„	170	„	from 0 per cent. to 0·5 per cent. must come off.
„	210	„	from 2 per cent. to 4 per cent. must come off.
„	235	„	from 6 per cent. to 16 per cent. must come off.
„	355	„	from 40 per cent. to 55 per cent. must come off.

The distillation shall be gradual, and should be fully completed in forty minutes from the first drop. Thermometer readings to be corrected for emergent stem.

In the process of treatment of the blocks not more than 2 per cent. of water will be permitted. The distillate from 170 degrees C. to 210 degrees C. will be approximately tar acids. Not more than 2 per cent. of sawdust or other foreign matter will be permitted. (From 210 to 235 degrees C. will be naphthalene.)

United States Forest Service Specifications.

The creosote should be derived from the distillation of pure coal tar, free from any adulteration whatever or any mixture of undistilled tar. If it contain more than 3 per cent. of water, a deduction in price corresponding to the per cent. of water in excess of that amount will be made. It shall have a specific gravity at 60 degrees C. of not less than 1·04. When analyzed by the standard Forest Service method of analysis for coal-tar creosote, it shall have the following fractions, calculated on a moisture-free basis (when less than 3 per cent. of water is present in the creosote, it shall be considered moisture free): —

(*a*) Up to 205 degrees C., not more than 5 per cent.

(*b*) Up to 235 degrees C., not more than 40 per cent. nor less than 5 per cent.

(*c*) Up to 250 degrees C., not more than 50 per cent. nor less than 15 per cent.

(*d*) Up to 295 degrees C., not more than 65 per cent. nor less than 30 per cent.

(*e*) At 355 degrees C. the residue must be soft and not sticky.

On applying the sulphonation test to the fraction between 305 degrees C. and 320 degrees C. there shall be no oily residue insoluble in caustic alkalies.

The indices of refraction at 60 degrees C. shall be as follows for the following fractions:

(*a*) At 250 degrees C., not less than 1·593 nor more than 1·602.

(*b*) At 290 degrees C., not less than 1·615 nor more than 1·622.

(*c*) At 300 degrees C., not less than 1·625 nor more than 1·632.

CREOSOTED ROUND PILING

The following table (G. B. Shipley, *Industrial Progress*) gives economical sizes for piling and poles that can be cut from whole trees.

If creosoted piling is dapped through, or is cut off at the top, so as to expose the untreated interior, it is necessary to

protect the parts so exposed with several coats of creosote oil, applied hot; or, if more convenient, a cement of equal parts of coal tar and air-slaked lime, applied hot, will answer the same end.

For all harbours of the North Atlantic coast, including those of Chesapeake Bay and its tributaries, 12 lb. of dead oil of coal tar are quite sufficient. For the harbours of the South Atlantic and Gulf, and the ports of the Caribbean Sea, 15 to 20 lb. per cubic foot, depending upon the exact location and the conditions governing the particular case, are required.

USUAL LENGTHS, SIZES AND SHIPPING WEIGHTS OF ROUND PILING

L'gth Feet	Diam. In.		Total Cu. Feet.	Total Wgt.		Diam. In.		Total Cu. Feet.	Total Wgt.	
	Top.	Butt.		12	20	Top.	Butt.		12	20
20	6	9	6·2	372	409	9	11	10·92	655	721
20	7	10	7·9	470	521	10	12	12·92	775	853
25	6	9	7·8	464	515	10	12	16·16	970	1,066
25	9	11	13·56	813	895	12	14	23·02	1,381	1,519
30	8	11	14·88	893	982	12	14	27·64	1,658	1,824
35	9	12	21·16	1,270	1,396	13	16	39·76	2,385	2,624
40	6	12	18·80	1,098	1,208	7	13	22·45	2,007	1,482
40	8	14	27·66	1,060	1,825	10	15	34·54	2,072	2,280
45	7	14	28·05	1,683	1,851	9	16	39·75	2,385	2,624
45	9	15	36·11	2,166	2,383	12	18	56·01	3,360	3,697
50	6	13	25·74	1,544	1,649	9	16	44·36	2,661	2,927
50	6	14	28·77	1,726	1,999	10	16	47·06	2,824	3,106
50	7	15	34·50	2,070	2,277	10	18	54·94	3,296	3,626
55	8	14	38·03	2,282	2,510	8	16	44·82	2,689	2,958
55	9	15	44·12	2,647	2,912	9	18	56·82	3,409	3,750
60	6	15	38·36	2,301	2,532	8	17	53·34	3,200	3,520
60	7	15	41·42	2,485	2,734	9	17	57·14	3,428	3,771
65	6	16	45·83	2,750	3,025	8	17	57·76	3,465	3,812
65	7	16	49·32	2,960	3,255	9	18	67·14	4,028	4,431
70	6	18	59·58	3,575	3,932	6	20	70·83	4,250	4,675
70	6	19	68·45	4,107	4,518	7	22	87·33	5,240	5,764
75	6	22	89·90	5,394	5,933	7	24	108·12	6,487	7,136
75	7	22	93·56	5,614	6,175	8	24	113·47	6,708	7,489
80	6	26	126·20	7,572	8,329	7	26	131·88	7,913	8,704
85	6	26	134·11	8,047	8,851	7	26	140·15	8,409	9,250

LIST OF PRESERVATIVES TESTED SHOWING ESSENTIAL PROPERTIES AND KILLING POINT

HUMPHREY AND FLEMING: "Toxicity of Various Wood Preservatives," *Journal of Industrial and Engineering Chemistry*, February, 1914.

	Specific gravity at 60° C.	Per cent. distils below.							Killing Point (per cent.)	
		C. 180°	C. 215°	C. 245°	C. 275°	C. 305°	C. 320°	C. 360°	Fomes annosus.	Fomes pinicola.
Water-gas-tar creosote, No. 1101. .	1·058	About 7·0	About 10·0	—	16·3	About 22·0	About 27·0	56·4	40	40
„ „ No. 2233. .	1·042	3·0	6·7	21·2	35·3	48·5	53·7	77·6	between 3 and 4	—
„ „ No. 2235. .	0·995	3·3	12·8	37·7	61·7	75·3	80·3	—	Around 0·45	—
Coal-tar creosote, No. 1074	1·048	4·8	17·8	44·4	54·1	67·2	74·1	—	0·55	0·225
„ „ Fraction 1, No. 1094	0·934	35·1	78·3	—	—	—	—	—	0·30	0·225
„ „ „ 2, No. 1106	1·003	About 2 to 3	30·0	About 80·0	About 92·0	—	—	—	0·225	0·150
„ „ „ 3, No. 1107	1·045	—	0·9	16·2	40·2	77·7	85·0	—	0·325	0·125
„ „ „ 4, No. 1108	1·088	—	—	0·9	4·7	38·5	54·3	—	3·30	0·125
„ „ „ 5, No. 1109	1·150 (16·5°)	—	—	—	—	4·1	10·1	48·7	33	7·800
Avenarius Carbolineum, No. 1843 .	1·126	—	1·1	2·6	6·1	16·4	About 29·0	—	5·25	0·300

CREOSOTED CROSS ARMS FOR AERIAL ELECTRICAL CONDUCTORS

C. B. SHIPLEY, *Industrial Progress*, Milwaukee, Wis.

Trade No.	Length	Size		No. Pins	Cubic Feet.	Weight in Pounds of Oil per Cubic Foot.		
						10	12	15
1	2' 00"	3¼	4¼	2	0·182	10·1	10·5	11·
2	4' 00"	3¼	4¼	4	0·364	20·3	21·1	22·
3	6' 00"	3¼	4¼	6	0·548	30·0	31·2	32·6
4	8' 00"	3¼	4¼	8	0·728	40·6	42·2	44·1
5	10' 00"	3¼	4¼	10	0·910	50·6	52·7	55·1
6	12' 00"	3¼	4¼	12	1·092	60·8	63·3	66·1
7	2' 7"	3	4	2	0·214	11·7	12·4	12·7
8	5' 1"	3	4	4	0·404	22·7	26·0	24·7
9	7' 7"	3	4	6	0·635	35·4	36·8	37·4
10	10' 1"	3	4	8	0·847	47·3	49·1	49·7
11	12' 7"	3	4	10	1·054	58·9	64·1	61·8

For cross arms of any dimension and specification, a treatment of 12 lb. of oil per cubic foot is recommended.

CREOSOTED CROSS TIES for STEAM and ELECTRIC RAILWAYS, C. B. SHIPLEY, *Industrial Progress*, Milwaukee, Wis.

Dimensions.	Feet B.M.	Feet, Cubic.	WEIGHT.	
			10 lb. Oil.	12 lb. Oil.
4 × 6 × 5	10	0·833	45	48
4 × 6 × 6	12	1·000	55	58
5 × 6 × 5	12·5	1·040	57	60
5 × 6 × 6	15	1·250	69	72
5 × 6 × 7	17·5	1·475	81	85
6 × 8 × 6	24	2·000	110	116
6 × 8 × 7	28	2·333	128	135
6 × 8 × 7' 6"	30	2·500	138	145
6 × 8 × 8	32	2·666	146	154
6 × 8 × 8' 6"	34	2·833	156	164
7 × 7 × 7	28·5	2·390	132	138
7 × 7 × 8	32·6	2·716	149	157
7 × 7 × 8' 6"	34·6	2·891	159	167
8 × 8 × 9	48	4·000	220	232
8 × 8 × 10	53	4·416	243	256
8 × 8 × 12	64	5·333	293	309
8 × 10 × 10	66·6	5·555	305	322
8 × 10 × 12	80	6·666	366	004
8 × 10 × 14	93	7·750	426	449

Weights are for 10 and 12 lb. of oil, respectively, per cubic foot.

METHOD OF TREATING RED OAK TIES THAT SHOULD BE EMPLOYED FOR DIFFERENT PERIODS OF SEASONING

(*American Wood Preservers' Association*, 1915.)

Period of Seasoning.	Air Seasoning Only.	Steam and Vacuum.	Vacuum.	Boil in Creosote.	Steam and Air Seasoning.	Would not Treat.	Depends on Progress.	Depends on Weight or Moisture Determination.	Depends on Localities and Weather.	No Experience.	Total.
(*a*) Seasoned one year	18	0	2	1	0	0	2	1	0	9	33
(*b*) Seasoned six months, including summer . . .	9	1	2	1	0	6	2	2	1	9	33
(*c*) Seasoned one summer	5	3	2	1	1	7	2	2	1	9	33
(*d*) Seasoned four months . . .	2	3	1	1	1	12	1	2	1	9	33
(*e*) Seasoned two months . . .	0	2	0	2	1	19	0	0	0	9	33

ARTIFICIAL WOOD

Artificial wood consists of a composition which when in either a warm or wet condition is in a plastic condition, but which, on cooling or drying, becomes hard, and forms a material which resembles wood and can be used for the same purposes. The most usual uses are for mouldings, veneers, parquetry, etc. The method of manufacture consists in pulping or other suitable means of incorporation, pressure in moulds, drying in ovens, etc., according to the materials employed.

Artificial wood is generally composed of some of the following materials: Paper, paper pulp, glue, flour, sawdust, hemp, shavings, ivory and bone dust, albumen, resins, gums, metallic oxides, drying oils, gelatine, sulphur, caoutchouc, gun cotton, gutta percha, mineral salts.

The manufacture of artificial wood forms the subject matter of numerous patents.

CREOSOTED POLES FOR ELECTRIC RAILWAYS, TELEPHONES AND TELEGRAPH LINES [1]

G. B. Shipley, *Industrial Progress*, Milwaukee, Wis.

Shape.	Length.	Least Diam.		Total Cubic Feet.	Weight per Cubic Feet.		
		Top.	Butt.		10 Creosote.	12 Creosote.	15 Creosote.
Circular	25	5	10	7·85	438	450	475
	30	5	12	12·48	693	712	756
	35	6	13	18·00	999	1,034	1,089
	40	7	14	24·93	1,383	1,433	1,509
	45	7	14	28·05	1,557	1,611	1,648
	50	8	15	37·15	2,061	2,133	2,249
	55	8	16	44·78	2,485	2,573	2,711
	60	8	16	48·86	2,711	2,806	2,958
	65	8	17	56·85	3,155	3,265	3,442
	70	9	18	71·02	3,941	4,079	4,300
	75	9	18	81·22	4,507	4,666	4,916
	80	9	19	89·09	4,944	5,117	5,394
Octagon	25	5	10	6·99	388	415	420
	30	5	12	11·29	626	648	684
	35	6	12	14·41	800	828	872
	40	6	14	20·62	1,144	1,184	1,247
	45	7	14	25·14	1,395	1,444	1,522
	50	7	15	30·95	1,717	1,777	1,873
	55	8	15	36·78	2,041	2,113	2,227
	60	8	16	43·84	2,433	2,518	2,654
	65	8	17	51·98	2,884	2,986	3,147
	70	8	17	55·99	3,107	3,291	3,390
	75	8	18	65·27	3,623	3,749	3,952
	80	8	18	69·60	3,862	3,998	4,215
Square	25	4	9	7·69	426	442	465
	30	4	9	10·04	557	576	608
	35	5	11	16·26	902	934	984
	40	6	12	23·20	1,287	1,332	1,404
	45	6	12	26·25	1,456	1,506	1,589
	50	6	13	32·74	1,816	1,880	1,982
	55	7	14	43·66	2,423	2·507	2,643
	60	7	14	47·63	2,643	2,735	2,183
	65	7	15	55·42	2,870	2,970	3,131
	70	7	15	61·40	3,407	3,526	3,737
	75	7	16	72·17	4,005	4,145	4,369
	80	7	16	76·96	4,271	4,421	4,768

[1] Note.—Lengths are in feet; other dimensions are in inches. Weights are for treatments of 10, 12 and 15 lb. of oil respectively.

FACTORS FOR DETERMINING THE VOLUME OF CREOSOTE OIL[1] AT 100°F. (37·7°C.), WHEN THE OIL IS AT TEMPERATURES RANGING BETWEEN 60° TO 225°F. (15·5° TO 107·2°C.) [1]

G. B. Shipley, *Industrial Progress*, Milwaukee, Wis.

Temp. Fahr.	Factor.	Temp. Fahr.	Factor.	Temp. Fahr.	Factor.	Temp. Fahr.	Factor.
60	0·9822	102	1·0009	144	1·0196	186	1·0382
1	0·9827	3	1·0013	5	1·0200	7	1·0387
2	0·9831	4	1·0018	6	1·0204	8	1·0391
3	0·9836	5	1·0022	7	1·0209	9	1·0396
4	0·9840	6	1·0027	8	1·0213	190	1·0400
5	0·9845	7	1·0031	9	1·0218	1	1·0404
6	0·9849	8	1·0036	150	1·0222	2	1·0409
7	0·9853	9	1·0040	1	1·0227	3	1·0413
8	0·9858	110	1·0045	2	1·0231	4	1·0418
9	0·9862	1	1·0049	3	1·0236	5	1·0422
70	0·9867	2	1·0053	4	1·0240	6	1·0427
1	0·9871	3	1·0058	5	1·0245	7	1·0431
2	0·9876	4	1·0062	6	1·0249	8	1·0436
3	0·9880	5	1·0067	7	1·0253	9	1·0440
4	0·9885	6	1·0071	8	1·0258	200	1·0445
5	0·9889	7	1·0076	9	1·0262	1	1·0449
6	0·9894	8	1·0080	160	1·0267	2	1·0453
7	0·9898	9	1·0085	1	1·0271	3	1·0458
8	0·9902	120	1·0089	2	1·0276	4	1·0462
9	0·9907	1	1·0094	3	1·0280	5	1·0467
80	0·9911	2	1·0098	4	1·0285	6	1·0471
1	0·9916	3	1·0102	5	1·0289	7	1·0476
2	0·9920	4	1·0107	6	1·0294	8	1·0480
3	0·9925	5	1·0111	7	1·0298	9	1·0485
4	0·9929	6	1·0116	8	1·0302	210	1·0489
5	1·9934	7	1·0120	9	1·0307	1	1·0494
6	0·9938	8	1·0125	170	1·0311	2	1·0498
7	0·9943	9	1·0129	1	1·0316	3	1·0502
8	0·9947	130	1·0134	2	1·0320	4	1·0507
9	0·9951	1	1·0138	3	1·0325	5	1·0511
90	0·9956	2	1·0143	4	1·0329	6	1·0516
1	0·9960	3	1·0147	5	1·0334	7	1·0520
2	0·9965	4	1·0151	6	1·0338	8	1·0525
3	0·9969	5	1·0156	7	1·0343	9	1·0529
4	0·9974	6	1·0160	8	1·0347	220	1·0533
5	0·9978	7	1·0165	9	1·0351	1	1·0538
6	0·9983	8	1·0169	180	1·0355	2	1·0542
7	0·9987	9	1·0174	1	1·0360	3	1·0547
8	0·9992	140	1·0178	2	1·0365	4	1·0551
9	0·9996	1	1·0183	3	1·0369	5	1·0556
100	1·0000	2	1·0187	4	1·0373	—	—
1	1·0004	3	1·0192	5	1·0378	—	—

[1] Explanation.—To determine the volume at 100 degrees Fahrenheit, divide the volume at any temperature by the factor corresponding to that temperature in the above table.

ANALYSIS OF PRESERVATIVES USED IN PENETRATION TESTS

DR. H. VON SCHRENK AND A. L. KAMMERER, *Proceedings American Wood Preservers' Association*

	German Creosote	Carbolineum.	American Creosote.	Lyster Wood Creosote.	80 and 20 per cent. Mixture.
Sp. Gr. at 100° F. .	1·0642	1·1026	1·0336	1·0901	1·0699
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Tar Acids by Volume	7·0	4·0	8·5	75·0	6·75
Up to 200° C. . .	0·1	0·0	1·7	1·2	0·0
200 to 210° C.	1·5	0·0	5·2	0·5	0·6
210 to 235° C. .	9·5	0·0	35·6	9·1	26·7
235 to 270° C. . .	21·3	0·1	23·3	44·1	26·2
270 to 315° C. . .	23·9	13·2	12·7	30·9	12·4
315 to 355° C. . .	23·6	48·5	12·0	2·7	12·8
Residue	19·9	37·8	9·3	10·3	21·2
Water	0·0	0·0	0·0	1·1	0·0

FORMULA FOR FINDING CAPACITY OF CIRCULAR TANKS

A simple formula for quickly determining the approximate capacity of circular tanks for storing creosote or other antiseptic agent, which is stated to be accurate to within 1 per cent. for a tank of 5,000 barrels capacity, is given by Mr. S. R. Church, Manager of the Research Department of the Barrett Manufacturing Coy. (*Wood Preservers' Bulletin*, April–June, 1914), as follows: Diameter (in feet) squared × depth (in feet) ÷ $8\frac{1}{2}$ = capacity in 50 gallon barrels.

TO PRESERVE POSTS FROM DECAY.

Thoroughly season, char, and immerse in heated coal tar.

To Prevent Wood Cracking

Immerse the wood in a tank of paraffin wax heated up to 212 degrees Fahr. (100°C.) and retained at that temperature until it has ceased to give off air bubbles and then allowed to cool down to point of congelation. The wood should then be removed and the adhering wax scraped off.

THE EFFECT OF DRIVING CUT SPIKES INTO BORED HOLES UPON THEIR HOLDING POWER [1]

(All ties Red Oak untreated)

H. F. Weiss, *Proceedings American Wood Preservers' Association*

Method of Inserting Spike in Tie.	Resistance to Pull
	lb.
Ordinary $\frac{9}{16}$ inch square spikes driven without boring	7,513
Ordinary $\frac{9}{16}$ inch square spikes pointed on four sides, driven in hole $\frac{1}{2}$ inch in diameter . . .	8,178
Ordinary $\frac{9}{16}$ inch square spikes pointed on four sides, driven in hole $\frac{7}{16}$ inch in diameter . . .	7,836
Ordinary $\frac{9}{16}$ inch square spikes pointed on four sides, driven in hole $\frac{3}{8}$ inch in diameter . . .	7,664

Cubic Feet in One Ton of Different Woods.

The following are the cubic feet required for the woods named to weigh approximately one ton: Ash, 37 to 45; beech, 42 to 50; deals, 55 to 65; elm, 53 to 60; ebony, 27 to 30; fir (Baltic), 50 to 60; fir (Scotch), 60 to 65; lime, 56 to 59; mahogany, 34 to 36; maple, 46 to 48; oak (green), 32 to 39; oak (seasoned), 32 to 48; pine, 55 to 60; walnut, 50 to 53.

[1] Bulletin 118, Forest Service—*Prolonging the Life of Cross Ties*—By Howard F. Weiss.

CRUSHING STRENGTH OF CROSS TIES IN PER CENT OF WHITE OAK

H. F. Weiss, *Proceedings American Wood Preservers' Association*

Kind of Tie: Common Name	Kind of Tie: Botanical Name	Fibre Stress at Elastic Limit Perpendicular to Grain Lb. per sq. in.	Fibre Stress in per cent of White Oak, or 853 lb. per sq. in.
Osage Orange	Toxylon Pomiferum	2,260	265·0
Honey Locust	Gleditsia Triacanthos	1,684	197·5
Black Locust	Robinia Pseudacacia	1,426	167·2
Post Oak	Quercus Minor	1,148	134·6
Pignut Hickory	Hicoria Glabra	1,142	133·9
Water Hickory	,, Aquatica	1,088	127·5
Shagbark Hickory	,, Ovata	1,070	125·4
Mockernut Hickory	,, Alba	1,012	118·6
Big Shellbark Hickory	,, Laciniosa	997	116·9
Bitternut Hickory	,, Minima	986	115·7
Nutmeg Hickory	,, Myristicaeformis	938	110·0
Yellow Oak	Quercus Velutina	857	100·5
White Oak	,, Alba	853	100·0
Bur Oak	,, Macrocarpa	836	98·0
White Ash	Fraxinus Americana	828	97·1
Red Oak	Quercus Rubra	778	91·2
Sugar Maple	Acer Saccharum	742	87·0
Rock Elm	Ulmus	696	81·6
Beech	Fagus Atropunicea	607	71·2
Slippery Elm	Ulmus Pubescens	599	70·2
Redwood	Sequoia Sempervirens	578	67·8
Bald Cypress	Taxodium Distichum	548	64·3
Red Maple	Acer Rubrum	531	62·3
Hackberry	Celtis Occidentalis	525	61·6
Incense Cedar	Libocedrus Decurrens	518	60·8
Hemlock	Tsuga Canadensis	497	58·3
Long-leaf Pine	Pinus Palustris	491	57·6
Tamarack	Larix Laricina	480	56·3
Silver Maple	Acer Saccharinum	456	53·5
Yellow Birch	Betula Lutea	454	53·2
Tupelo	Nyssa Aquatica	451	52·9
Black Cherry	Prunus Serotina	444	52·1
Sycamore	Platanus Occidentalis	433	50·8
Douglas Fir	Pseudotsuga Taxifolia	427	50·1
Cucumber Tree	Magnolia Acuminata	408	47·8
Short-leaf Pine	Pinus Echinata	400	46·9
Red Pine	,, Resinosa	358	42·0
Sugar Pine	,, Lambertiana	354	41·5
White Elm	Ulmus Americana	351	41·2
Western Yellow Pine	Pinus Ponderosa	348	40·8
Lodgepole Pine	,, Contorta	348	40·8
Red Spruce	Picea Rubens	345	40·5
White Pine	Pinus Strobus	314	36·8
Engelman Spruce	Picea Engelmanni	290	34·0
Arborvitæ	Thuja Occidentalis	288	33·8
Largetooth Aspen	Populus Grandidentata	260	30·5
White Spruce	Picea Canadensis	262	30·7
Butternut	Juglans Cinerea	258	30·3
Buckeye (yellow)	Aesculus Octandra	210	24·6
Basswood	Tilia Americana	209	24·5
Black Willow	Salix Nigra	193	22·6

EFFECT OF TREATING TIES UPON THEIR CRUSHING STRENGTH AND SPIKE-HOLDING POWER[1]

H. F. Weiss, *Proceedings American Wood Preservers' Association*

Kind of Wood.	Treating Process Used.	Crushing Strength at Elastic Limit Perpendicular to Grain in Per Cent. of Untreated Tie.	Resistance to Spike Pulling in Per Cent. of Untreated Tie with Cut Spikes.	
			Cut Spikes.	Screw Spikes.
Red Oak	Untreated	100	100	173
	Burnettized	97	98	172
	Lowry	104	93	163
	Rueping	92	93	162
	Full Cell	104	101	172
Loblolly Pine	Untreated	100	100	215
	Rueping	99	123	209
	Lowry	104	94	219
	Rueping	112	109	246
	Full Cell	100	84	184
	Crude Oil	73	53	192
Short-leaf Pine	Untreated	100	100	241
	Rueping	103	100	209
	Full Cell	108	103	223
	Crude Oil	72	45	176
Long-leaf Pine	Untreated	100	100	202
	Rueping	109	100	205
	Full Cell	101	015	270
Red Gum	Untreated	100	100	228
	Rueping	97	102	222
	Full Cell	99	105	252
	Crude Oil	90	70	270

[1] A part of the differences in strength here noted is due to varying moisture contents of the ties and the fact that different ties had, of course, to be used, it being impossible to keep these absolutely uniform.

Data taken from experiments made under the direction of Dr. W. K. Hatt and published in the bulletins of the American Railway Engineering Association.

STANDARD SIZES OF TELEGRAPH POLES
RICHARD WADE, SONS & CO.

EXTRA STOUT.

Length.	Minimum Diameter. At Top.	Minimum Diameter. At 5 ft. from Butt.	Recommended Depth in Ground.	Estimated Cubic Contents for Carriage.
Ft.	In.	In.	Ft.	
26	7½	10¼	5	10·5
28	7½	10½	5 to 6	12
30	7½	10¾	5 to 6	13
32	7½	11	5 to 6	15
34	7½	11¼	5 to 6	16·5
36	7½	11½	6 to 7	18
38	7½	11½	6 to 7	20
40	7½	12	6 to 7	21
45	7¾	13	6 to 7	26
50	7¾	13¾	6 to 7	34
55	8	14¾	6 to 7	44
60	8	15½	7	48
65	8	16¼	7	55
70	8	17	7	65
75	8	17¾	8 to 9	75
80	8	18¾	8 to 9	85
85	8	20	8 to 9	95

STOUT.

Length.	Minimum Diameter. At Top.	Minimum Diameter. At 5 ft. from Butt.	Recommended Depth in Ground.	Estimated Cubic Contents for Carriage.
Ft.	In.	In.	Ft.	
18	5½	7¼	5	4
20	5½	7½	5	4·6/10
22	5½	7¾	5	5·3
24	5½	8	5	6·3
26	5¾	8¼	5	7·3
28	6	8¾	5 to 6	8·61
30	6	9	5 to 6	10
32	6¼	9¼	5 to 6	11
34	6¼	9¾	5 to 6	12·5
36	6½	10	6 to 7	14
38	6½	10¼	6 to 7	15
40	6½	10¾	6 to 7	17·5
45	6¾	11½	6 to 7	22·5
50	7	12¼	6 to 7	29
55	7½	13¼	6 to 7	35
60	7½	13½	7	42
65	7½	14¼	7	46
70	7½	14¾	7	50
75	8	15¼	8 to 9	55
80	8½	15¾	8 to 9	65
85	8½	15¾	8 to 9	75

LIGHT.

Length	Minimum Diameter. At Top.	Minimum Diameter. At 5 ft. from Butt.	Recommended Depth in Ground.	Estimated Cubic Contents for Carriage.
Ft.	In.	In.	Ft.	
18	5	6	5 to 6	3
20	5	6	5 to 6	3·7/10
22	5	6¼	5 to 6	4·1
24	5	6½	5 to 6	4·6
26	5	6¾	5 to 6	5·3
28	5	7	5 to 6	6
30	5	7¼	5 to 6	7
32	5	7¼	5 to 6	7·5
34	5	7½	5 to 6	8·5
36	5	7¾	6 to 7	9·5
38	5	8	6 to 7	10·5
40	5	8	6 to 7	12
45	5¼	8¾	6 to 7	15
50	5¼	9½	6 to 7	20

STANDARD SIZES AND WEIGHTS OF SLEEPERS

		Uncreosoted.	Creosoted 6 lb.
9 feet	10 in. × 5 in.	about 17 pieces to ton;	about 16 pieces to ton.
9 "	9 in. × 4½ in.	" 21 " "	" 20 " "
6–8 "	4 in. × 8 in.		

X

ELASTIC DEFLECTION OF WOODEN TELEGRAPH POLES

RICHARD WADE, SONS & Co.

Overall Length in feet.	Length from Ground to point of loading in feet.	Elastic Deflection in inches for a load of 100 lb. apart from give in the Foundations.													
		Single Poles, either with or across the line.							A Poles, applied across the line.						
		Diameter in inches 5 ft. from the Butt.							Diameter in inches 5 ft. from the Butt.						
		6	7	8	9	10	11	12	6	7	8	9	10	11	12
20	13	1·4	0·8	0·5	0·3	0·2	0·1	0·1	0·03	0·02	0·01	0·01	—	—	—
26	19	4·4	2·4	1·4	0·9	0·6	0·4	0·3	0·09	0·05	0·03	0·02	0·01	0·01	—
28	21	6·0	3·2	1·9	1·2	0·8	0·5	0·4	0·12	0·06	0·04	0·03	0·02	0·01	0·01
30	23	7·9	4·3	2·5	1·6	1·0	0·7	0·5	0·16	0·09	0·06	0·03	0·02	0·01	0·01
32	25	10·1	5·5	3·2	2·0	1·3	0·9	0·6	0·20	0·11	0·06	0·04	0·03	0·02	0·01
34	27	12·8	6·9	4·0	2·6	1·6	1·1	0·8	0·26	0·14	0·08	0·05	0·03	0·02	0·02
36	29	15·8	8·5	5·0	3·2	2·0	1·4	1·0	0·32	0·17	0·10	0·06	0·04	0·03	0·02
38	31	19·3	10·4	6·1	3·9	2·4	1·7	1·2	0·40	0·21	0·12	0·08	0·05	0·03	0·02
40	33	23·3	12·5	7·4	4·6	3·0	2·1	1·5	0·47	0·25	0·15	0·09	0·06	0·04	0·03
45	38	—	19·1	11·2	7·0	4·6	3·1	2·2	0·71	0·38	0·22	0·14	0·09	0·06	0·04
50	43	—	—	16·1	10·2	6·7	4·9	3·2	1·03	0·56	0·33	0·20	0·13	0·09	0·06
60	53	—	—	—	19·0	12·5	8·5	6·0	1·93	1·04	0·62	·38	0·24	0·17	0·12

Note.—The deflection of an A pole in the direction of the line is half that of a single pole. The deflections are given to the $\frac{1}{100}$th of an inch.

THE BLEEDING AND SWELLING OF PAVING BLOCKS

CLYDE H. TEESDALE, American Wood Preservers' Association.

In a very interesting paper Mr. Teesdale deals with tests made on a practical scale to ascertain the cause of the bleeding and swelling of wood paving-blocks and the effect of varying the method of treatment on the latter, and gives full details of the materials used, the method of conducting the work, and discusses the results of the various tests. The paper is illustrated by a number of diagrams showing the effect of vacuum on bleeding; the influence of steaming on bleeding; the bleeding of green and air-seasoned blocks; the bleeding of long-leaf pine, and rapid growth of loblolly pine blocks; the effect of varying absorption on bleeding; the effect of external pressure on bleeding; the bleeding of air-dry hemlock blocks; the effect on swelling of using various mixtures of creosote with carbon-free tar (specific gravity 1·184); the effect on swelling of using various mixtures of creosote and carbon-free by-product tar (specific gravity 1·232); the effect on swelling of using various mixtures of creosote and carbon-free gas-house tar (specific gravity 1·273); the effect on swelling of using a mixture of creosote and by-product tar (specific gravity 1·184) containing various amounts of free carbon; the effect on swelling of using a mixture of creosote and by-product tar (specific gravity 1·232) containing various amounts of free carbon; the effect on swelling of using a mixture of creosote and gas-house tar (specific gravity 1·273) containing various amounts of free carbon; the effect of vacuum on swelling using an average absorption of about 10 lb. per cub. ft. (soaking tests); the effect on vacuum on swelling using an average absorption of about 16 lb. per cub. ft. (soaking tests); the effect of vacuum on swelling using an average absorption of about 10 lb. per cub. ft. (sand cushion test); the effect of vacuum on swelling using an average absorption of about 16 lb. per cub. ft. (sand cushion test); the effect of varying absorption on swelling (soaking test); the effect of varying absorption on swelling (sand cushion test); and the difference in swelling of the tops and the bottoms of blocks (sand cushion test).

The following are the general conclusions arrived at by Mr. Teesdale: "These tests seem to indicate that long-leaf

pine paving should be treated in the green condition after being well steamed. All blocks, even if thoroughly air-seasoned, should be well steamed. While it is true that a preliminary and final vacuum greatly retarded bleeding and to some extent the swelling of air-seasoned wood, a preliminary vacuum will tend to make the absorption of oil too rapid during treatment, resulting in uneven penetration. A steaming period is, therefore, advisable to render the absorption less rapid and allow a longer and more intense pressure period to be applied. Furthermore, if seasoned blocks are steamed, they will take up moisture and expand and should be less liable to give trouble from swelling after laying in the street. For these reasons it would be preferable to treat green material when it is possible to obtain it.

"If for any reason the blocks cannot be laid soon after treatment, they should be covered and perhaps wetted occasionally to prevent them from drying out. It is likely that if the blocks are wet when laid, expansion troubles will be much reduced, provided a good job of laying is done.

"It would seem to be desirable to give a vacuum treatment after the steaming period and also after the oil has been removed from the cylinder. If tar mixtures are used, a final steam bath should succeed the final vacuum to remove carbon and dirt from the blocks.

"Absorptions of over 16 pounds per cubic foot hardly seem necessary. Data are available which show that heavier absorptions do not greatly retard swelling and they tend to increase bleeding.

"It seems very likely that the reasons why some pavements bleed while others do not may very often be traced to the method used in treatment. A plant treating green material would resort to a steaming and vacuum treatment with the result probably that the blocks would give no trouble. The same plant, perhaps, would later treat seasoned material without steaming it or giving it a vacuum treatment. This would be the simplest method of treating such timber as much time would be saved, and these operations would seem unnecessary.

"These tests do not indicate that the use of tar mixtures will prevent swelling, although they tend to retard it. The

least swelling was obtained with large amounts of gas-house tar having a high viscosity and specific gravity. Previous tests, however, have shown that such tar mixtures greatly retard penetration. The tar most suitable for mixing with creosote, when their penetrating qualities are considered, are those having the lowest per cent. of free carbon, and possibly those having low specific gravities and viscosities. These tests indicate that such tars do not greatly retard swelling. It would seem, therefore, that the only justification for mixing tar in oils to be used for treating paving-blocks is to lower its cost.

"Furthermore, the tests indicate that increasing the absorption of oil above 10 pounds per cubic foot does not tend to appreciably decrease swelling. It would seem, therefore, that in drawing up specifications for treating blocks, the waterproofing effect of the oil or treatment should not receive much consideration. The main points to be considered (aside from the selection of wood) should be to have sufficient oil of good grade to obtain a thorough penetration in order to avoid decay, and to specify a method of treatment that will not cause the blocks to bleed. The tests also indicate that swelling should be controlled principally by having the blocks in the green condition when laid in the street. and by taking special care with the filler and method of laying so that water will not penetrate to the bottom of the blocks."

TIMBER-TREATING PLANTS IN THE UNITED STATES.

Mr. E. L. Powell states (Proceedings of the Association of Engineering Societies, 1914, vol. 52) that there are in the United States ninety-four wood-preserving plants, each capable of treating or preserving an average of 30,000,000 feet board measure per annum. According to the same authority the various steam and electric railways use about 150,000,000 ties or sleepers per annum.

TABLE OF PRINCIPAL WOODS

COMPILED FROM VARIOUS SOURCES

Local Name.	Botanical Name.	Principal Locality of Origin.	Qualities, etc.
Abies	Abies Smithiana	India	Easily split
Acacia	Acacia Aribica	,,	Close-grained, tough
,,	,, Catecha	,,	Strong, durable
,,	,, Elata	,,	,, ,,
,,	,, Lencophlæa	,,	Close-grained, tough
,,	,, Modesta	,,	Very hard, tough
,,	,, Pendula	Australia	,, ,, ,,
,,	,, Speciosa	India	Somewhat brittle
,,	,, Stipulata	,,	Strong, large timber
Advenanthera	Adenanthera pavonia.	,,	Strong, not stiff
Alder	Alnus glutinosa	Europe	Hard
Almond	Amygdalus communis	South Europe, etc.	,,
Amboine		Africa	Fancy
Apple	Pyrus Malus	America, Europe	Medium tough
Arbor vitæ	Thuja Occidentalis	Temperate climates	Soft
Ash	Fraxinus excelsior	Britain, etc.	Hard, tough
,, black	,, Sambucifolia	United States	,, ,,
,, blue	,, quadrangulata	,, ,,	,, ,,
,, white	,, Americana	,, ,,	,, ,,
Aspen largetooth	Populus grandidentata	,, ,,	Soft
Assegai-wood	Curtisia faginea	Africa	Very tough
Balata		West Indies	Hard, durable
Bamboo	Bambusa arundinacea	China, India, etc.	Hard
Bassia (oil or butter tree or Phulwara, shea-tree)	Sapotaceæ.	East Indies, etc.	Hard

Basswood	Tilia Americana	United States	Soft, flexible
Beech	Fagus Sylvatica	Europe	Hard
,,	,, Americana	United States	,,
,,	,, atropunicea	,, ,,	,,
,,	,, ferruginea	United States	,,
Big shellbark hickory	Hicoria raciniosa	,, ,,	,,
Birch	Betula Alba	Europe	,,
,, black or cherry	,, lenta	United States, etc.	,,
,, paper	,, papyracea or paprifer	America	,,
,, red or river	,, nigra	,, etc.	,,
,,	,, alba populifolia.	,,	,,
,, yellow or gray	,, lutea	,,	,,
,, white	,, populifolia	,,	,,
Bitternut hickory	Hicoria minima	,,	,,
Biti		India	Open grain
Blackbutt	Eucalyptus pilularis	Australia	Moderately strong
Black gum	Nyssa sylvatica	America, etc.	Medium
Black Botany baywood		Australia	Hard
,, or cherry birch	Betula lenta	Europe, etc.	,,
Blue gum	Eucalyptus globulas.	Australia	,,
Bog oak		Ireland, etc.	,,
Boxwood	Buxus sempervirens	Europe	,,
Brazil wood	Cæsalpina echinata	S. America	Moderately hard
Brush box	Tristania conferta	New South Wales	,, ,,
Buckeye	Æsculus glabra	United States	Soft, spongy
,, yellow	,, Octandra	,, ,,	,, ,,
Bukkum, see Wukkum.			
Bullet-tree	Achras sideroxylon	West Indies, Guiana	Hard
Bull pine	Pinus ponderosa	United States	Medium
Bur-oak	Quercus macrocarpa	Africa	Hard, tough
Butternut	Juglans cinerea	United States.	Soft

Local Name.	Botanical Name.	Principal Locality of Origin.	Qualities, etc.
Button wood	Acer pseudo-platanus	Temperate climates	Soft
Calamander	Diospyros quæsita	Ceylon	Very hard
Camphor wood	Laurus camphora	Warm climates	Soft
Cam wood		Africa	Moderately hard
Canary wood		Brazil	,, ,,
Cangica wood		,,	,, ,,
Catalpa	Catalpa bignonoides	United States	Durable
Cedar	Cedrela australis	New South Wales	Soft
,, bastard	Libacedrus decurrens	California	,,
,, incense	,, ,,	United States.	,,
,, red	Juniperus virginiana	United States	,,
,, yellow	,, californica	,, ,,	,, lasting
,, Spanish		South America	,,
,, Western	Juniperus occidentalis	United States	,,
,, W. Indies	Cedrela odorata	W. Indies	,,
,, White	Cupressus thyoides	United States	,,
,, ,,	Thuya occidentalis	,, ,,	,,
Cedar wood	Cedrus libani	Lebanon	,,
Cherry	Prunus cerasus	Europe	,,
Cherry, wild (black)	,, serotina	United States	Medium
,, tree	Exocarpus cupressiformis	Australia	Hard
Chestnut	Castanea vesca	Europe and America	Medium
Coco-wood		West Indies	Hard
Cogwood	Laurus chloroxylon	West Indies	Hard
Colonial teak	Flindersia australis	New South Wales	,,
Coquilla-nut	Attalea funifera	Brazil	,,
Cork-oak	Quercus suber	Europe	Bark affords cork

Cotton or tupelo gum	Nyssa aquatica	United States, etc.	Medium
Cotton-wood	Populus monilifera	United States	,,
Cowdi pine	Dammara australis	Temperate climates	Durable
Crab apple	Pyrus coronaria	United States	Hard
Cuban pine	Pinus heterophylla	,, ,,	Medium
Cucumber tree	Magnolia acuminata	,, ,,	,,
Cypress	Cupressis sempervirens, etc.	S. United States	Soft
,, bold	Taxodium distichum	W. ,, ,,	,,
,,	Torreya taxifolia	New Zealand	Hard
Dammar	. . . .	East Indies, New Zealand, New Guinea	Medium (resin)
Deodar	Cedrus deodar	Himalayas and India	Very durable
Dogwood	Bedfordia salicina	Tasmania	Hard
,,	Cornus florida	United States	,,
,,	Piscidia erythrina	West Indies	,,
Douglas fir	Pseudotsuga taxifolia	United States	Medium
Douglas pine	Abies douglassii	Gt. Britain, etc.	Medium
East India blackwood	Dalbergia latifolia	India	Heavy, close-grained
Ebony	Diospyros ebenus	India, Africa, etc.	Hard
,,	Byra ebenus	West Indies	,,
Elder	Sambucus nigra	Europe and America	Soft
Elm	Ulmus campertris, etc.	Europe	Hard, durable
,, red	,, fulva	United States	Medium
,, rock	,,	,, ,,	,,
,, slippery	,, pubescens	,, ,,	,,
,, white	,, americana	,, ,,	,,
Fir, red silver	Abies amabilis	Sierra Nevada	,,
,, Scotch	Pinus sylvestris	Europe	,,
Fir, Noble	Abies nobilis	America	Medium
Fir, silver	Abies grandis	California	,,

Local Name.	Botanical Name.	Principal Locality of Origin.	Qualities, etc.
Fustic	Morus tinctoria	America, N. and S.	Medium
Greenheart	Nectandra rodiæi	West Indies, etc.	Hard, durable
Grey box	Eucalpytus hemiphloia	New South Wales	,,
,, **ironbark**	,, paniculata	,, ,, ,,	,,
Gum, black	Nyssa sylvatica	United States	,,
,, sour	,, multiflora	,, ,,	,, tough
,, spotted	Eucalyptus maculata	New South Wales	Moderate
,, sweet or red	Liquidamber styraciflua	United States	Medium hard & tough
,, tupelo or cotton	Nyssa aquatica	,, ,,	Medium
,, grey	Eucalyptus punctata	New South Wales	,,
Hackberry	Celtis occidentalis	United States.	,,
Hackmatack	See Larch, Tamarack		
Hawthorn	Cratægus oxyacantha	Europe, etc.	Hard
Hazel	Corylus avellana	,,	,,
Hemlock, Eastern	Tsuga canadensis	U.S., Canada	Medium
Hemlock spruce	Abies canadensis	North America	Medium
Hemlock, Western	Tsuga heterophylla	,, ,,	,,
Hickory (Eastern shell-bark)	Carya alba	United States (East of Alleghanies)	Hard
,, (Western shell-bark, etc.)	,, sulcata, etc.	United States (Mississippi Valley)	,,
Holly	Ilex aquifolium	Europe	,,
,,	,, opaca	United States (S.E.)	,,
Hoonsay	. . . .	India	Ornamental
Hornbeam	Carpinus betulus	Europe	Hard
Horse-chestnut	Æsculus hippocastana	Asia and Europe	Soft
Huon pine	Dacrydium franklinii	Tasmania	Hard

Ironwood	Bumelia lycioides	United States (E.)	Hard
,, (redwood)	Exythoxylon areolatum	West Indies	,,
Jack pine	Pinus divaricata	United States	,,
Jack-wood	Artocarpus integrifolia	Asia, Ceylon, etc.	,,
Jarrah	Eucalyptus rostrata	Western Australia	Hard, resists sea-worms and ants
Jeffery pine	Pinus jefferyi	United States	Medium
Jujube	Zizyphus jujuba	India	Hard durable
Juniper red rock, yellow, and Western cedar	Juniperus virginiana, Californica, Bermudiana, Occidentalis, Sabina	Europe, Siberia, U.S.	Soft
Karri		Australia	Hard
Kiaboca wood		India	Ornamental
King-wood		Brazil	Hard
Knob-cone pine	Pinus attenuata	Pacific Coast	,,
Kowrie pine		New Zealand	Resin
Laburnum	Cistisus alpinus, etc.	Europe	Hard
Lancewood	Anona duquetia	S. America	,,
,, black	Oxandra virgata	West Indies	,,
Larch	Larrix europæa	Europe	Durable
,, Western	,, occidentalis	Oregon, U.S.	
Laurel, mountain	Kalmia latifolia	Pennsylvania, etc.	Hard
Leopard, snake or letter-wood	Piratinera guianensis	Central America, British Guiana, etc.	Ornamental
Lignum vitæ	Guiacum officinale	West Indies	Very hard
,, ,,	,, Sanctum	S. Florida	Hard
Lime	Tilia europæa	Europe	Close-grained
Linden (Linn, basswood)	Tilia americana	United States (E.)	Soft, flexible
Loblolly pine	Pinus tacda	,, ,,	Medium
Locust	Hymenæa courbaril	West Indies	Hard

Local Name.	Botanical Name.	Principal Locality of Origin.	Qualities, etc.
Locust, black	Robinia pseudacacia	United States (East of Mississippi River)	Tough, durable
„ **honey**	Gleditsia triacanthos	„ „	„ „
Lodge-pole pine	Pinus contorta	United States.	Hard
Logwood	Hacmatoxylon campechianum	West Indies	Dyewood
Longleaf pine	Pinus palustris	United States	Medium
Mahogany	Swietenia mahagoni	Central America, Cuba, etc.	Hard
„ **red**	Eucalyptus resinifera	New South Wales	Medium
„ **mountain**	Cereocarpus ledifolius	Rocky Mountains	Hard
„ **white**	Eucalyptus acmenoides	New South Wales	Medium
Mahwa	. . . .	Bengal	Hard, strong
Mangrove	Numerous	Tropical countries	Moderate
Maple, black	Acer nigrum	United States (E.)	Hard
„ **red**	„ rubrum	„ „	Soft
„ **silver or soft**	„ saccharinum	„ „	Hard
„ **sugar or hard**	„ saccharium	„ „	Hard
Mockernut hickory	Hicoria Alba	„ „	Medium
Mountain ash	Eucalyptus pilularis	Australia	Hard, tough
„ „	„ sieberiana	New South Wales	„ „
„ „ **rowan**	Pyrus aucuparia	Gt. Britain, etc.	Medium.
Mulberry	Morus alba et nigra	China, Europe	Soft
„ **red**	„ rubra	United States (E.)	Medium, very durable
Muskwood	Eurybia argophylla	Tasmania, N. South Wales	Hard
Mustaiba	. . . .	Brazil	Hard
Myrtle	Myrtus communis	South Europe	„
„ **Tasmanian**	Fagus cunninghamii	Tasmania	Ornamental
Nellec	. . . .	India	„

Nettle-tree	Celtis australis	South of Europe	Close-grained
Norfolk Island pine	Araucaria excelsa	Norfolk Island	Medium
Norway spruce	Abies excelsa	Norway	,,
Novaladdi	. . . .	India	Close-grained
Nutmeg	. . . .	Moluccas, etc.	Medicinal
Nutmeg hickory	Hicoria myristicæformis	United States	Medium
Oak	Quercus robur, etc.	Europe, etc.	Hard
,, African	Oldfieldia africana	Africa	,,
,, black	Quercus tinctoria	United States (E.)	,,
,, chestnut	,, prina	,, ,,	,,
,, cork	,, tuber	South France and Spain	Bark used for corks
,, pin	,, palustris	United States	Hard
,, post	,, minor	,, ,,	,,
,, red	,, rubra	,, ,,	,,
,, scarlet	,, coccinea	United States, etc.	,,
,, shingle	,, imbricata	,, ,,	,,
,, Spanish	,, digitata	,, ,,	,,
,, white	,, alba	,, ,,	,,
,, yellow bark	,, velutina	,, ,,	,,
Olive	Olea europæa	Europe, Syria, etc.	Medium
Oregon pine	See Douglas fir.		
Osage orange (Bois d'arc)	Maclura aurantiaca	United States (S.)	,,
Osiers	Salix viminalis, etc.	Europe	Soft
Oyster Bay pine	Callitris australis	Tasmania	Hard
Paddle wood	Aspidosperma excelsum	Guiana	Very hard
Palm	Cocos nucifera	Tropics	Soft (oil)
Paper birch	Betula papyrifa	United States	Hard
Partridge wood	Heisteria coccinea, etc.	South America, etc.	Hard
Pear	Pyrus communis	. . . .	,,
Pheasant wood	Same as partridge wood	. . . .	,,
Pig nut hickory	Hicoria glabra	United States	,,

Local Name.	Botanical Name.	Principal Locality of Origin.	Qualities, etc.
Pin oak	Quercus palustris	United States	Hard
Pine	Very numerous	Europe, Asia	Medium
,, Cuban	Pinus heterophylla	United States	,,
,, loblolly	,, taeda	,, ,,	,,
,, pitch	,, rigida	,, ,, (S.E.)	,,
,, pond	,, seretina	,, ,,	,,
,, red	,, resinosa	,, ,, (E.)	,,
,, Scots	,, sylvestris	Scotland, etc.	,,
,, shortleaf	,, echinata	United States	,,
,, spruce	,, glabra	S. Carolina and S.	,,
,, sugar	,, lambertiana	United States, etc.	,,
,, table mountain	,, pungens	,, ,,	,,
,, white	,, strobus	,, ,, (E.)	,,
,, yellow	,, jeffreyi	California	,,
,, yellow (Southern)	,, mitis	Northern America	,,
,, ,, (Western)	,, ponderosa	,, ,,	,,
,, long-leaf	,, palustris	,, ,,	,,
Pitch pine	,, rigida	United States, etc.	,,
Plane, occidental	Platanus occidentalis	,, ,,	,,
,, oriental	,, orientalis	Asia	,,
,, or sycamore	Acer pseudo-platanus	Gt. Britain, etc.	Soft
Plum	Prunus domestica	,, ,,	,,
Pond pine	Pinus seretina	United States	Medium
Poon wood	Calophyllum angustifolia	India	,,
Poplar	Populus alba, etc.	Europe and Asia	,,
,, white, tulip tree	Liriodendron tulipifera	United States (E.)	,,
Porcupine wood	Cocos nucifera	Tropics	Ornamental

Pui		West Indies	Hard, tough durable
Purple-heart	Copaifera pubiflora	Brazil	Hard
Quassia	Simaruba amara.	Surinam, etc.	Used in medicine
Ratans	Calamus rotang	Tropics	Cane
Red fir	See Douglas fir.		
Red birch	Betula nigra	United States, etc.	Hard
Red maple	Acer rubrum	America	Medium
Red oak	Quercus rubra	United States, etc.	Hard
Red sanders (ruby wood)	Pterocarpus santalinus	India	Dye wood, etc.
Red or sweet gum	Liquidambar styrachiflua	United States, etc.	Hard
Red wood	Sequoia gigantea	California	Medium
,, ,,	,, sempervirens	United States	,,
Rhododendron	Rhododendron, various	Himalaya	Hard
Rose wood	Dalbergia	Central America, etc.	Moderately hard
,, African	Pterocarpus erinaceus, etc.	Gambia	Hard
,, Tasmanian	Acacia	Tasmania, etc.	,,
Sandal wood	Santalum album	India	Soft
Sappan wood	Cæsalpina sappan	,,	Dye wood, etc.
Sassafras	Atherosperma moschata	Tasmania	Hard
,,	Sassafras officinalis	America	,, medium
Satin wood	Chloroxylon swientenia	India	Ornamental
Saul or Sâl	Shorea robusta	,,	Hard
Scarlet oak	Quercus coccinea	United States, etc.	,,
Scots fir	Pinus sylvestris	Scotland, etc.	Medium
Sepe		West Indies	Hard, insect-proof
Service tree	Amelanchier canadensis	United States (E.)	Hard, durable
Shagback hickory	Hicoria ovata	,, ,,	Medium
She oak	Casuarina quadrivalvis	Tasmania	Hard
Shingle oak	Quercus imbricata	United States, etc.	,,
Shortleaf pine	Pinus echinata	,, ,,	Medium

Local Name.	Botanical Name.	Principal Locality of Origin.	Qualities, etc.
Silver wood	Leucadendron argenteum	Cape of Good Hope	Hard
Silver or soft maple	Acer saccharinum	America	Soft
Sissoo	Dalbergia sissoo	India	,,
Snake, letter or leopard wood	Piratinera guianensis	South America and W. Indies	Ornamental
Sneeze wood	Pteroxylon utile	South Africa	Hard, durable, resists white ants and shipworm
Spanish oak	Quercus digitata	United States, etc.	Hard
Spindle tree	Eunonymus europæus	Gt. Britain	Soft
Spruce, black	Abies douglassii	Sierra Nevada	,,
,, Engelmann's	Picea engelmanni	Rocky Mountains	,,
,, red	,, rubens or Pinus mariana	,, ,,	,,
,, white	,, canadensis	United States	,,
Stringy bark	Eucalyptus fabrorum	Australia	Hard
Sugar or hard maple	Acer saccharium	America	,,
Sycamore	Acer pseudo-platanus	Temperate climates	Soft
,,	Platanus occidentalis	United States (E.)	Hard
,, (fig)	Ficus sycomorus	Egypt	Light, durable
Table Mountain pine	Pinus pungeus	United States, etc.	Medium
Tallow wood	Eucalyptus microcorys	New South Wales	Hard
Tamarack (Eastern)	Larix americana	United States (N. & N.E.)	Medium, durable
,, (Western)	,, occidentalis	,, ,, (W.)	,, ,,
,,	,, laricina	,, ,,	,,
Teak, African	Oldfieldia africana	West Africa	Hard
,, Indian	Tectona grandis	India	,,
Thorn	Cratægus punctata	United States (E.)	,,

Toon wood	Cedrela toona	India	Hard
Toqua	. . . . .	Himalaya	Ornamental
Tulip wood	Harpulia pendula	Australia, etc.	Hard
Tupelo	Nyssa aquatica	United States	Medium
Turpentine	Syncarpia laurifolia	New South Wales	Hard, resists teredo
Turtle wood	. . . . .	Surinam	,,
Ubbariya	. . . . .	Ceylon	Medium, durable
Vegetable ivory	Phytelephas macrocarpa	Central America	Nut used in turnery
Walnut, black	Juglans nigra	United States (E.)	Medium
Walnut, English	,, regia	Europe, etc.	Hard
,, French	. . . . .	Persia, Asia Minor, etc.	,,
,, white or butter-nut	,, cinerea	United States (E.)	Soft
Water hickory	Hicoria aquatica	,, ,,	Medium
Western yellow pine	Pinus ponderosa	,, ,,	,,
White wood	Pittosporum bicolor, etc.	New South Wales, etc.	Hard
White stringy bark	Eucalyptus eugenoides	,, ,, ,, ,,	,,
Willow	Salix, various	Europe and America	Soft
,, black	,, nigra	United States	,,
Woolly butt	Eucalyptus longifolia	New South Wales	Hard
Wukkum or Bukkum-wood	Cæsalpinia sappau	East Indies, Ceylon, etc.	Dye wood
Yacca wood	. . . . .	Jamaica	Medium
Yate	. . . . .	Australia	High tensile strength
Yellow bark oak	Quercus velutina	United States, etc.	Hard
,, fir	See Douglas fir.		
Y ,, or grey birch	Betula lutea	United States, etc.	,,
Yew	Taxus baccata	Gt. Britain, etc.	,,
,,	,, brevifolia	California and Oregon	,,
Zebra wood	. . . . .	Brazil	Ornamental

WOODS COMMONLY USED

Holtzapffel

For Building

Shipbuilding

Cedars
(Firs)
Elms
Firs
Larches
Locust
Oaks
Teak, etc., etc.

Wet Works, piles, foundations, etc.

Alder
Beech
Elm
Oak
Plane-tree
White Cedar

House Carpentry

(Firs)
Oak
Pines
Sweet chestnut

For Machinery and Millwork

Frames, etc.

Ash
Beech
Birch
Deals
Elm
Mahogany
Oak
Pines

Rollers, etc.

Box
Lignum vitæ
Mahogany

Teeth of Wheels, etc.

Crab tree
Hornbeam
Locust

Foundry Patterns

Alder
(Firs)
Mahogany
Pine

For Turnery

Common Woods for Toys: Softest.

Alder
Asp
Beech } small
Birch } small
Sallow
Willow

Best Woods for Tunbridge-ware

Holly
Horse-chestnut } White woods
Sycamore } White woods
Apple-tree
Pear-tree
Plum-tree

Hardest English Woods

Beech, large
Box
Elm
Oak
Walnut

For Furniture

Common Furniture and Inside Works

Beech
Birch
Cedars
Cherry-tree
(Fir)
Pines

Best Furniture

Amboyna
Black ebony
Cherry-tree
Coromandel
Mahogany
Maple
Oak, various kinds
Rose wood
Satin wood
Sandal wood
Sweet chestnut
Sweet cedar
Tulip wood
Walnut
Zebra wood

MISCELLANEOUS PROPERTIES

Elasticity

Ash
Hazel
Hickory
Lance wood
Sweet chestnut, small
Snake wood
Yew

Inelasticity and Toughness

Beech	Lignum vitæ
Elm	

Colouring Matter

Brazil Brazilletto Cam wood Log wood Nicaragua Red Sanders Sapan wood	Red dyes	Green ebony, green dye Oak Walnut

Even Grain, proper for Carving

Lime-tree	Pine
Pear-tree	

Durability in Dry Works

Cedar	Sweet chestnut
Oak	Yellow deal
Poplar	

Colouring Matter

Fustic Zante	Yellow dyes	Rose wood Sandal wood Satin wood Sassafras	Scent
Camphor wood			
Cedar	Scent		

SPECIFIC COHESION AND STRENGTH OF WOOD

Prof. Wallace

Alder	1·506
Ash	1·804 to 1·274
„ red (seasoned)	1·899
„ white	1·509
Bay	1·547 to 1·085
Beech	1·880
Cedar	0·528
Chestnut 100 years in use	1·291
Citron	1·357 to 0·868

Cypress	0·732 to 0·542
Elder	1·086
Elm	1·432
Fir	1·380 to 0·879
,, pitch pine	1·398 to 0·380
,, strong red	1·172
,, Memel, seasoned	1·154
,, Russian	1·062 to 0·963
,, American	0·942
,, yellow deal	0·900
,, white	0·455
,, Scotch	0·711
,, Scotch, seasoned	0·837 to 0·745
Lancewood	2·621
Larch	1·177
Lemon	1·004
Mahogany, Spanish	1·283
Maple, Norway	1·123
Mulberry	1·492
Oak	1·085 to 0·936
,, English	1·085 to 0·936
,, ,, seasoned	1·509
,, French	1·060 to 0·960
,, ,, seasoned	1·559 to 1·363
,, Baltic	1·211
,, American white	1·009
,, Dantzic	0·818
Plum	1·357 to 1·205
Pomegranate	1·221 to 0·882
Poplar	0·705 tp 0·488
Teak, Java, seasoned	1·509
,, Pegu	1·400
,, Malabar	1·395
Willow	1·375 to 0·809

RESISTANCE OF WOOD TO PRESSURE

PROF. WALLACE

American pine	1,606 lb.
Elm	1,284 ,,
English oak	3,860 ,,
White deal	1,928 ,,

The yate wood of Australia is said to be one of the strongest woods in existence. It is reported by the Australian government to have an average tensile strength of 24,000 lb. to the square inch. The yate tree grows to a height of 100 ft. and attains a diameter of 2½ ft.

TABLE OF SPECIFIC GRAVITIES OF SEASONED TIMBER

W. Templeton.

	Specific Gravity	Lb. cubic feet	Cub. ft. = 1 ton
Alder	736	46	48¾
Apple	792	49½	45¼
Ash	845	52	43
Beech	852	53¼	42
Birch, English	792	49½	45¼
" American	648	40½	55
Black wood	662	41¼	54
Blue gum	1,100	68¾	32¾
Box, French	1,328	83	27
" Dutch	912	57	39
Cedar, American	561	35	64
" Sydney	560	34¾	64
" Canadian	910	57	39¼
Cherry-tree	715	45	50
Chestnut	610	38	59
Cork	240	15	149
Cowdi pine	512	32	70
Crab-tree	768	48	46¼
Ebony, Indian	1,208	75½	29
" American	1,331	83	27
Elm	673	42	53
Hawthorn	610	38	59
Holly and hornbeam	760	47½	47¼
Ironbark	1,233	77	29
Laburnum	920	57½	39
Lance wood	1,023	64	35
Larch	530	31	72¼
Lemon-tree	704	44	51

	Specific Gravity.	Lb. cubic feet.	Cub. f. = 1 ton.
Lignum vitæ	1,336	83½	26½
Lime-tree	760	47½	47¼
Log wood	913	57	39½
Mahogany, Spain	720	45	50
„ Honduras	560	35	64
Maple	752	47	47½
Oak, English	934	58	38½
„ American	672	42	53¼
„ African	944	59	38
Orange-tree	705	44	49¾
Pear-tree	660	41	54½
Pine, pitch	736	46	48¾
„ red	672	42	53
„ white	456	28½	78½
„ yellow	448	28	80
Poona	640	40	35
Poplar	384	24	93¼
Plum-tree	785	49	45¾
Red gum	901	56	40
Rose wood, black	1,280	80	28
Sycamore	624	39	57½
Teak	750	46	48½
Walnut	671	42	53½
Willow	585	36½	61¼
Yew, Spanish	807	50½	44¼
„ Dutch	788	49¼	45

COMPOSITION OF WOODS

Woods.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
	Per cent	Per cent	Per cent	Per cent	Per cent
Beech	49·36	6·01	42·69	0·91	1·00
Birch	50·20	6·20	41·62	1·15	0·81
Oak	49·64	5·92	41·16	1·29	1·97
Poplar	49·37	6·21	41·60	0·96	1·86
Willow	49·96	5·96	39·65	0·96	3·37

CLASSIFICATION OF TIMBER ACCORDING TO SIZE

Balk	12 in × 12 in. to 18 in × 18 in
Whole timber	9 in × 9 in. to 15 in × 15 in
Half timber	9 in × 4½ in to 18 in × 9 in
Scantling	9 in × 4 in to 12 in. × 12 in
Quartering	2 in. × 2 in to 6 in × 2 in
Planks	11 in to 18 in. × 3 in to 6 in
Deals	9 in × 2 in. to 4½ in.
Battens	4½ in. to 7 in × ½ in to 3 in.
Strips and laths	2 in to 4½ in. × ½ in to 1½ in

PERCENTAGE OF WATER IN AIR-SEASONED WOOD

Spons, *Mechanics' Own Book*

Beech	18·6	Birch	30·0	Pine red	39·7
Poplar	26·0	Oak red	33·7	Chestnut	38·2
Sugar and com.		„ white	35·5	Poplar, Italian	48·2
Maple	27·0	Pine, white	37·0	„ black	51·8
Ash	28·0	„ „	45·5	Linden	47·1

MEASUREMENT OF TIMBER

To measure standing timber take the length as high as the tree measures 24 in. in circumference. At one-half of this height the measurement to be taken is the mean girth of the timber in the stem of the tree. One-quarter of this girth is taken as the side of the equivalent square area. All branches, so far as they measure 24 in. in diameter, are included as timber in the measurement.

It is the usual custom for the buyer to have the right to choose any particular part as the girding place intermediate between the butt end and the half height of the stem.

Number of cubic feet in one ton of seasoned timber: Ash 45, beech 51, elm 60, fir 65, mahogany 34, oak 39.

Four methods of measuring timber: quarter girth, true content, die square, and squared or calliper measure. For example, taking a tree 20 feet in length by 24 inches in diameter,

the measurement by each of these methods will be as follows:

Quarter girth	45 ft. rough measure
True content	62 ft. cube
Die square (17 in. square)	40 ft. cube
Calliper measure	74 ft.

CONTENTS, SIZES, AND WEIGHTS OF TIMBER

40 cubic feet unhewn timber = 1 load.
50 ,, ,, squared ,, = ,,
600 superficial feet 1-inch planks or deals = 1 load.
400 ,, ,, 1½ ,, ,, ,, = ,,
300 ,, ,, 2 ,, ,, ,, = ,,
240 ,, ,, 2½ ,, ,, ,, = ,,
200 ,, ,, 3 ,, ,, ,, = ,,
170 ,, ,, 3½ ,, ,, ,, = ,,
150 ,, ,, 4 ,, ,, ,, = ,,

One square (100 ft. superficial) of flooring requires:

12¼ 12 ft.deal boards, rough.
12½ ,, ,, ,, edges shot
13 ,, ,, ,, wrought and laid folding.
13½ ,, ,, ,, ,, ,, ,, straight joint.
14 ,, ,, ,, ,, ploughed and tongued.
16 ,, battens, rough.
16½ ,, ,, edges shot.
17 ,, ,, wrought and laid folding.
18 ,, ,, ,, ,, ,, straight joint.

TIMBER MEASURE

1 load of unhewn timber	= 40 cub. ft.
1 load of squared timber	= 50 ,,
1 ton of shipping	= 42 ,,
1 stack	=108 ,,
1 cord	=128 ,,
1 Christiania standard	=103½ ,, (120 boards 11 ft. by 1¼ in. by 9 in.)
1 Petrograd (Petersburg) standard	=165 cub. ft. (120 deals 6 ft. by 3 in. by 11 in.)
1 London standard	= 270 cub. ft. (120 deals 12 ft. by 3 in. by 9 in.)
1 Dublin standard	= 270 cub. ft. (120 deals 12 ft. by 3 in. by 9 in.)

1 Quebec standard	= 229⅙ cub. ft. (100 deals 10 ft. by 3 in. by 11 in.)
1 Square	100 sq. ft. super.

NOTE.—Boards sold by the square can be of any thickness, viz.: 200 boards 6 ft. long by 12 in. in width measure 12 squares whatever their thickness. For example, if ½ in. thick, it would be 12 squares of ½ in. stuff. If ¾ in. thick, it would be 12 squares of ¾ in. stuff, etc., etc.

PROPER TIME TO FELL TREES, ETC.

Any tree showing any incipient signs of disease should, of course, be immediately felled. Winter and summer are the best times for felling, as the trees are then less full of sap. Trees of a resinous nature are best felled during the summer months, whilst for other trees the winter is the most suitable time. Oaks and other trees from which the bark is stripped should be felled in the spring, at which time the bark is more readily removable. The boles of the trees should always be severed as near the ground as practicable. The wood surrounding the heart of the tree is the weakest, and the older the tree the more marked is this feature. To judge the condition, strength or value of timber requires experience. When, however, the condition is very poor, it can be readily distinguished by its having a loose and woolly fibre. Ill-conditioned timber also when sawn is inclined to clog the teeth of the saw, and has a white and floury appearance when cut.

TO ASCERTAIN WEIGHT OF TIMBERWORK, FLOORING, ETC.

Multiply breadth by length in feet by thickness in inches, and by one of following factors: Elm 3·50 lb., yellow pine 3·42 lb., white pine 2·97 lb., dry oak 4·85 lb., for timber work and flooring.

Multiply length in feet by breadth and depth in inches and product by one of following factors: Elm 2·92 lb., yellow pine 2·85 lb., white pine 2·47 lb., dry oak 4·04 lb., for timber beams, posts, and joists.

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Wm. Rider & Son, Ltd., 8–11 Paternoster Row, London, E.C.